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Review & Analysis

Runway Incursion: Human Factors In Runway Incursions

Prepared for: Federal Aviation Administration,
Office of the Chief Scientific and Technical Advisor
for Human Factors (AAR–100)

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11. SUPPLEMENTARY NOTES
This document is the final report on issues relevant to runway incursions at civilian airports. The document contains a summary of the literature on runway incursion issues and solutions, gathered from international sources, and contains pertinent non-copyrighted citations from both international and domestic databases.

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13. ABSTRACT ***(Maximum 200 Words)***

The runway incursion issue is a major concern for the Federal Aviation Administration (FAA) and is one of the top five aviation safety issues for FY 2000 for the FAA Administrator. It is such a significant problem that the Administrator has established a new Runway Incursion Safety Program Office that reports directly to her. The Program Office has responsibility for coordinating multiple taskings in this area across several internal FAA offices. As a part of this overall FAA effort, the Office of the Chief Scientific and Technical Advisor for Human Factors/AAR-100 has asked HSIAC to conduct (1) a search of domestic and international literature/databases on human factors issues of runway incursions and (2) a written review of the key documents from international sources. This document contains a summary of these key documents followed by the citations and abstracts gathered from the literature search.

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SECTION I. SUMMARY OF KEY LITERATURE SEARCH DOCUMENTS

INTRODUCTION{ TC "1. INTRODUCTION" \F C \L "1" }

In support of the Federal Aviation Administration, Office of the Chief Scientific and Technical Advisor for Human Factors (AAR-100), the Human Systems Information Analysis Center (HSIAC) conducted an extensive search of national and international scientific literature to identify state-of-the-art research relevant to human factors risks, problem identification, and risk mitigation of airport runway incursion. This volume contains the literature search results from searched databases, and a summary of the key international articles retrieved in this search.

A runway incursion is defined as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land."[1] In recent years the number of runway incursions has been on the rise, with a 75% increase since 1993.[2] This increase is likely due to a combination of factors which may include, an increase in the number of flight operations worldwide, an increase in the complexity of runway configurations, taxiway connections, and operational procedures, and increases in simultaneous aircraft surface movements. The situation can be exacerbated by weather conditions causing low visibility, and problems with communications between pilots and controllers.

The reduction in the number of runway incursions has become a priority for the Federal Aviation Administration (FAA), and has been identified by the FAA Administrator as being one of the top five aviation safety issues for FY 2000. To that end the Administrator has established a new Runway Incursion Safety Program Office that reports directly to her.

While is has been suggested that runway incursions are generally related to "pilot error," a recent report on the topic by MITRE Corporation[3] suggests that, due to factors listed above, pilots are increasingly being exposed to situations that make them more vulnerable to making errors. Furthermore, the report contends that available resources for reducing such situations are not being fully utilized. Runway safety can only be assured by implementing adequate procedures, improved training, better airport lighting, marking and signage, and new technology solutions. The following sections review some of the current developments that may help to reduce the occurrence of runway incursion, with

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1 *Federal Aviation Administration (April 1995) Airport Surface Movement Safety: Runway Incursion Action Plan. Washington, DC.*

2 *McKenna, J. T. (2000). Runway incursions top U.S. air safety risks. Aviation Week & Space Technology, 152(5), 26-28.*

3 *Kelley, D. R., & Adam, G. L. (1997). The Human Factors of Runway Incursions Caused by 'Pilot Error': A Survey of U.S. Airline Pilots. In R. S. Jensen and L. A. Rakovan (Eds.) Proceedings of the Ninth International Symposium on Aviation Psychology, Volume 2 (911-917).*

an emphasis on technology solutions under development at research and development centers outside of the United States.

DOMESTIC AND INTERNATIONAL SOURCES ON RUNWAY INCURSIONS

The United States is focusing more heavily on reporting runway incursions compared to other countries. Peter Quaintmere of IFALPA indicated that other countries have a runway incursion problem, but that it is not currently considered an international issue. Dan Maurino (ICAO) added support to this comment. The US is possibly leading the world in reporting runway incursions; US ALPA is presently the driving force within IFALPA for the reporting of runway incursions.

International databases contain substantial numbers of abstracts from scientific, operational, and news sources that address the domestic US runway incursion problem. Very few abstracts (i.e., fewer than 5%) addressed the runway incursion issue outside of the US. While some runway incursions within the US appear to be "domestic" incursions, they involve international flight crews. Language is a persistent problem. Indeed, language usage was a problem in the Tenerife accident in 1977.

RUNWAY INCURSION SOLUTIONS - TRAINING, PROCEDURES & SIGNAGE

Certain perspectives found in the literature on runway incursions deem the issue to be a "people problem," and suggest that this problem is caused by those involved, and will persist until people stop making mistakes. While there is some basis to this perspective, it only serves as a valid basis to *describe* the problem and not to *solve* the problem. Treating the problem – as a people problem – with additional procedures, training and legislation may help in reducing incursions in the short term, but may also serve to burden the end users (i.e., pilots and controllers) with additional workload. Procedures and training targeted at the end user should, in the long term, be only a part of a larger incursion treatment package that analyzes, identifies, and removes the sources of error, rather than forcing users to work around sources of error. Moreover, procedures and training should be standardized internationally.

Airport signage, markings, and lighting are essential fixes. Moore[4] stated that "The trouble with today's runway holding position visual aids (marking, signs, and in some cases, lights) is that the meaning of the signal, and the action to be taken upon encountering the signal, differs depending on the issued clearance. The marking, signs, and lights are ambiguous. The single exception is the stopbar; even then, I've encountered at least one unswitchable stopbar at Brussels National Airport. It was supposedly scheduled to have switching capability added, but I have not gone back to see if the change was made." Moore suggests variable clearance signs as a potential remedy. Ultimately, the chosen fix must be simple, intuitive, and internationally accepted (and applied).

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[4] *Moore, M. (2000). Runway incursions: Awareness & prevention. Part 1. Air Line Pilot, 69(3), 16-17.*

RUNWAY INCURSION SOLUTIONS - TECHNOLOGY INSERTION

A fresh perspective of the incursions problem is needed, and a city traffic control analogy is one new way to look at the situation. Although it is possible to get lost while driving, even the most remote intersection can be equipped with a clear, real time (albeit static) instruction to STOP. No reliance is placed on long term memory for determining at what point to stop (i.e., a crossing restriction). It is important to note that the analogy breaks down as the STOP instruction is not addressed to any particular car (as a clearance would be in the flight environment), but the point remains that drivers are not burdened to use long-term memory for crossing restrictions. Ground clearances, on the other hand, contain both navigation instructions and crossing restrictions. Contrast this with a typical city driving scenario. While the driver is inherently burdened with navigation, crossing restrictions are a natural, given part of the built environment. Navigation by itself is a significant challenge for anyone who has driven in an unfamiliar city. Imagine if the driver were also responsible for storing and activating information on crossing restrictions simultaneously: "Go to the corner of first street and main via maple, Jefferson, and main. Hold short of maple and wait for the blue BMW 4-door to cross. Follow the BMW and…" In the driving analogy, even navigation information is available via GPS-equipped rentals in major cities. McKenna[5] stated, "While improved training and cockpit procedures can help, safety officials said a technological solution to the runway incursion threat is essential. 'We do ground operations at airport the same way we did them 40 years ago,' said one industry analyst deeply involved in FAA incursion research. 'The controller has no way of detecting a potential collision and identifying the aircraft involved quickly other than with his eyeballs and a pair of binoculars. We have pilots taxiing $60-million airplanes using a paper map on their laps. That's Flintstones technology.'

Technological insertion in the form of new (and integrated) ground and airborne controls/displays designed to increase pilot and controller situational awareness is an essential component in treating the runway incursion problem. While our findings in the international literature were disappointing in terms of raw numbers of abstracts returned, we identified a number of technological programs that deal directly with the sources of error, and have substantial potential to reduce the runway incursion problem. In fact, in contrast to work in the United States, the majority of the published research from international sources, on issues related to runway incursions, such as collision avoidance, and airport navigation, focus on technological solutions to the problem. Most notable of these efforts are the Improved Airport Guidance (IMAGE) program and the Taxi Ramp Management and Control (TARMAC) program conducted at the Delft University of Technology and the DLR's Institute of Flight Guidance, respectively.

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[5] *McKenna, J. T. (2000). Runway incursions top U.S. air safety risks. Aviation Week & Space Technology, 152(5), 26-28.*

Improved Airport Guidance (IMAGE)[6]

One technology solution to RI is being developed under the Improved Airport Guidance (IMAGE) program, underway at the Delft University. This research and development program will use a pair of heads-down cockpit displays for navigation, guidance, and situation awareness data, to optimize aircraft ground operations. The objectives of the program are twofold: (1) optimize airport capacity, and (2) increase the safety for aircrafts' ground operations, especially under conditions of degraded visibility (e.g. fog, inclement weather). Although the authors focused on the implications of its system under low visibility conditions, there are clear implications for overall runway safety. By allowing safe navigation and operation under low visibility conditions, the system contributes to increased situation awareness and collision avoidance. There are overlapping requirements for navigation guidance and collision avoidance (e.g., knowledge of your own location and status, and the locations of others). In addition, the author contends that implementation of the IMAGE systems will be relatively cost effective because it will add to the functionality of legacy systems rather than require an extensive cockpit modernization effort necessary for other technology solutions (e.g., the T-NASA HUD system).

The IMAGE concept architecture will use an aircraft's onboard Electronic Flight Instrument System (EFIS) to provide a perspective view and a plan view of airport operations, to be displayed on the Primary Flight Display (PFD) and Navigation Display (ND), respectively. The plan view will display a digital moving map of the airport along with the aircraft's own position, heading and speed, as well as the information regarding other aircraft on the runway area. The perspective display will provide a exocentric view of the airport as would be seen from a position outside and above the aircraft. This display will include all essential signs, markings, and runway structures. The advantage of the perspective display is that it will allow the pilot to maneuver the aircraft under any condition, and it could display dynamic signs and markings. Moreover, research at the Delft University of Technology has suggested that an exocentric perspective display may be better than plan view displays and egocentric displays for collision avoidance. Finally, navigation commands regarding taxi routes and clearances will be displayed via datalink. Commands from the datalink will be displayed on the Command Display Unit and/or the perspective and plan view displays.

The objectives of IMAGE require the integration of several technologies: the Differential Global Positioning System (DGPS); a local radio broadcast system, and the addition of a sensor on the nose wheel of each aircraft. The DGPS will provide position, orientation and heading data, and each aircraft will be required to broadcast its DGPS information at regular intervals. This data will be received by the air traffic control. Air traffic control will receive the DGPS data, combine it with a Secondary Surveillance Radar picture, and will then transmit the collective picture back to all aircraft on the runway for display on their EFIS. This requires a high performance radar system and a robust data broadcast

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[6] Meijer, R. (1998). Considerations on simulations to verify a system concept for improved airport guidance. In: AIAA Modeling and Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 10-12, 1998, Collection of Technical Papers (pp. 500-508), Reston, VA & The Netherlands: American Institute of Aeronautics and Astronautics.

system to redistribute data to participating aircraft. A sensor on the nose wheel could be used in combination with the DGPS to display a predicted course. This prediction can be used to detect and alert the pilot of possible collisions or incursions.

The common picture transmitted from the air traffic control station will be displayed on the plan view map, which include information about all aircraft on the runway overlaid onto a map of the airport. Other vehicles will be displayed to allow the pilot to detect possible problems and avoid collisions. These functions can be implemented by adding the display rendering software to the aircraft's Display Electronics Unit.

The proposed system will heighten situation awareness, minimize workload on both pilot and air traffic controller, and reduce errors, through explicit display and guidance of ground operations. In addition, the author argued that it is a cost effective solution because it adds functionality to current systems (i.e. the EFIS, and current radio broadcast capabilities).

At the time of this publication, the IMAGE system test and evaluation plan included a series of simulations, beginning with a number of part task simulation experiments and trials using a low cost road vehicle. This will lead to the final design, which will then be implemented on an aircraft as part of the Delft University's Cessna Citation II.

Taxi Ramp Management and Control (TARMAC)[7]

The German national aerospace research center and space agency (the DLR) is currently involved with the development of an airport traffic management system called TARMAC (Taxi Ramp Management and Control) The TARMAC system is an advanced SMGCS (Surface Movement Guidance and Control System) concept for an integrated airport surface movement management system. The program was launched in November 1997 and will end in 2001.

TARMAC is a systems approach that examines operational requirements and proposes technical solutions to those requirements. Specifically, the TARMAC program was developed to address a lack of planning and conflict detection tools, the need for better coordination for departure and arrival management, and for better human machine interfaces, all of which are contributors to the occurrence of runway incursions. To ensure user-centered technology solutions, the DLR will include input from German airport, airline, and ATC representatives.

There are six primary objectives for the TARMAC project: (1) develop new solutions, system components, and procedures for an integrated SMGCS, (2) verify the SMGCS concept as an efficiency and safety improvement approach, (3) deliver validated parameters for standardization bodies, (4) assure user-centered technological insertion, and (5) develop, test, and optimize key elements of an advanced SMGCS, and finally (6) proceed in a cost effective manner. To this end, the TARMAC program includes three

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[7] *This section is based on information gathered from the TARMAC web site at: http://www.dlr.de*

systems: the TARMAC-PL addresses operational problems as well as planning functions, the TARMAC-CN addresses the surveillance and communication aspects, and the TARMAC-AS, which addresses crew situation awareness on the ground. The airborne system (TARMAC-AS) will be described below.

The TARMAC-AS (Airborne System)

The TARMAC-AS is a cockpit solution for future SMGCS. This system, much like the IMAGE system, includes a situation-awareness display of the airport layout, the position of one's own aircraft, cleared taxi routes, and the positions of other vehicles. This information is graphically displayed on an aircraft's navigation display during ground maneuver. The system supports all weather position tracking and navigation, and presentation of the aircraft navigation information, which is generated by the planning system (i.e., TARMAC-PL) and transmitted through data link. The system performs an internal situation analysis of aircraft position, orientation and heading, and planning data, in order to generate warnings of path deviations or possible conflicts.

The TARMAC-AS uses a "situation assessment and analysis module" which generates an action plan for the crew based on the airport database, their own aircraft's position, other vehicle traffic, and the pilots actions with respect to the situation. The situation assessment module then displays the appropriate information on the navigation display. If the module detects a runway incursion, the TARMAC-AS stops the aircraft automatically. In addition, data received though the datalink system, such as clearances, planning times, positions, and status of other traffic participants, are also considered for the situation assessment and analysis.

The map and situation awareness information (infrastructure, traffic, clearance) are displayed on the existing navigation display. User preferences are accommodated by allowing the crew to select a number of display modes and scales. TARMAC-AS uses legacy equipment, consequently, it can be used to add functionality to existing modern cockpits. For example, in addition to the navigation display, it uses the existing FCU (Flight Control Unit) for system inputs. TARMAC-AS is also compatible with existing position tracking sensors, such as the GPS receiver. However, the situation assessment module does require a database containing aircraft parameters and airport structure.

The display of TARMAC-AS was developed using user-centered display design guidelines, and offers the following functionality:

- Display of the airport with runways, taxiways, parking positions, and buildings
- Flexible and situation dependent display modes, and zoom levels (The system is capable of selecting appropriate situation-dependent zoom level.)
- Display of the cleared taxi route represented by a green line on the map display
- Color coding for runways in accordance with their occupancy status
- Color coded display of the other traffic participants
- Display of the planning data generated by the traffic planning system

- Continuous display of the maximum steering angle depending on the current taxi speeds
- Display of warnings of runway incursion, taxi route deviation, and conflict situations

Currently, the TARMAC-AS is available as a prototype on a Silicon Graphics workstation. In addition, a test vehicle has been equipped with onboard equipment, including an INS, DGPS, SSR Mode-S transponder, data collection and storage devices, telemetry, laser reflector, and several communication systems. This equipment has also been installed in a DLR Demonstration Cockpit for further testing.

Ongoing efforts include: (1) verification of the system under operational conditions and with various airlines, (2) standardization of the TARMAC-AS database, (3) integration of TARMAC-AS with DLR's Enhanced Vision System (EVS) in order to provide additional capabilities for the detection of obstacles under low visibility conditions.

Other efforts are underway in non-US centers of research and development that address the runway incursion issue in some capacity. However, they are not comprehensive technology solutions compared to the IMAGE and TARMAC systems described above. Three such efforts are the extended machine perception system (MPS), the synthetic vision and precision navigation and taxi guidance system, and the runway incursion alert (RIA) tool.

Machine Perception System (MPS) [8]

The MPS is designed primarily as a method of tracking an aircraft's position and state, for the purposes of autonomous take-off, navigation and landing. However, since it is capable of detecting landmarks and obstacles, and their relationship to an aircraft, it could also be adapted as a runway incursion avoidance tool.

The MPS uses an aircraft's onboard sensors (e.g., GPS, gyros, accelerometers, etc), in combination with a image processing system, to determine the state and position of an aircraft. The aircraft's state is used by an aircraft navigation system to move the aircraft towards appropriate waypoints or to land safely, without input from a pilot or the crew. The image processing system includes a runway obstacle and tracking (RODT) module, which can recognize objects and detect possible conflicts or collisions. It is this module that is most germane to the problem of runway incursions. The RODT module is based on object detection and recognition software that was developed for autonomous automobile operations. It uses an optical device (e.g., conventional cameras) to scan a runway area for objects (e.g., aircraft, trucks, debris). If an object is detected, that meets a number of criteria (e.g., the algorithm determines that an object detected is of an appropriate size to be an aircraft or vehicle), an obstacle alert is sent to the MPS and appropriate measures are taken to avoid an incident.

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[8] ***Fuerst, S., Werner, S., Dickmanns, D., & Dickmanns, E.*** *(1997). Landmark navigation and autonomous landing approach with obstacle detection for aircraft. In the Proceedings of SPIE, Vol. 3088, p. 28-39.*

This system is completely self-contained, that is, all sensors, controls, and processing is onboard the aircraft. No ground based sensors or communications systems are necessary for the system to operate. However, this is both an advantage and a disadvantage, since coordination with air traffic controllers is an important part of runway safety. For example, the IMAGE system could provide both the pilot and the air traffic controller with a common picture of the environment. In contrast the autonomous MPS does not keep human operators in the loop. In addition, the image processing system could be subject to the same perceptual problems as human operators under low visibility conditions, in contrast to the systems described above. Although the system was not designed with the operator's situational awareness in mind, this type of technology does seem to have potential as an autonomous, or backup, collision detection and avoidance apparatus.

As of the publication date for this paper, the MPS had successfully completed real-time, hardware in-the-loop simulations of autonomous landmark navigation. The authors concluded that the image processes used for navigation and obstacle avoidance performed well enough to be considered for future precision aircraft navigation.

Synthetic Vision Precision Navigation And Taxi Guidance System[9]

Researchers at the University of Munich and the Technical University of Braunschweig have developed a guidance system for aircraft taxiing and surface movement. This system features the use of computer generated, synthetic vision to enhance on-board guidance, and to provide precision navigation capabilities.

The synthetic vision system presents operators with 2 and 3 dimensional graphical representations of airport structures to enhance situation awareness, especially for low visibility operations. This system is combined with precision navigation information provided by DGPS and inertial sensors. The synthetic vision system described by the author is similar in concept and functionality to the system developed at the University of Delft[10]. The two dimensional display is comprised of a plan view map generated from an airport terrain database, which will include the aircraft's own position and the positions of other aircraft, and runway elements including taxiways, aprons, parking positions, and buildings, as well as signs, marking, and stop bars. Additionally, the map can be zoomed to display any area of the airport. Further, color coding can be used to highlight important information, such as displaying a taxi route. The 3D perspective display provides an exocentric view of the current runway area. This exocentric display provides visual cues relevant to the task of navigation, such as deviation from the centerline of a runway.

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9 *Sachs, G., Moller, H., & Dobler, K. (1994). Synthetic vision and precision navigation for aircraft taxi guidance in low visibility. In the Proceedings of the American Institute of Aeraunotics and Astronotics, Guidance, Navigation and Control Conference. Scottsdale, AZ.*

10 *Theunissen, D. (1998). Structured specification of exocentric frames of reference. In the Proceedings of the American Institute of Aeraunotics and Astronotics, Modeling and Simulation Technologies Conference and Exhibit, Boston, MA.*

As of the date of this publication, the synthetic vision and guidance system has been installed on a test vehicle and used in experimental trials. These trials demonstrated high navigation precision under low visibility conditions. While the impetus for this system is the navigation difficulty and runway capacity reductions due to poor weather, it has the potential to provide improved situation awareness under all conditions - which is an important factor in reducing runway incursions.

Runway Incursion Alert (RIA) [11]

The Runway Incursion Alert tool (RIA) was developed by the National Aerospace Laboratory (NLR) of the Netherlands to detect conflicts or runway incursions by tracking the status of aircraft and other moving vehicles on the runway. Unlike other systems reviewed here, the RIA was developed primarily to be used by the air traffic *controllers* rather than by pilots in the cockpit. The RIA provides a knowledge-based controller decision aiding system that can reduce controller workload, and enable runway capacity to be optimized, while maintaining operational safety.

The RIA system consists of a two major components: a conflict detection function and a graphical user interface. The graphical user interface depicts an airport map, as well as dynamic, real-time, overlays of aircraft and other surface vehicles. When an incursion or conflict is detected, the display alerts controllers by highlighting, in red, the overlay symbols representing the vehicles involved. Additional context-specific information, such as the location of the conflict, the status, and identification of the aircraft involved, is displayed in a pop-up window.

The RIA conflict detection function uses knowledge about vehicles on the runway, and specific rules regarding their safe operation, to reason about where conflicts are likely to occur. Since the presence of runway incursions depends on a number of operational factors, the conflict detection function must take into account factors that have operational consequences including an aircraft's status (i.e., arrival, departure, etc.), its state (i.e., moving, standing, accelerating, etc), and its clearances. This knowledge, along with the known location and proximity of aircraft, can then used by the rule-based algorithms to determine whether the potential for conflict exists.

A prototype RIA system has been developed and demonstrated by the NRL, and evaluated by air traffic controllers. It is anticipated that this system will assist researchers in the understanding of how knowledge based expert systems can be used to enable airports to sustain throughput while maintaining safety, particularly for airports with complex surface operations and for low visibility conditions.

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11 *More information about the National Aerospace Laboratory and the Runway Incursion Alert tool can be found at:* http://www.nlr.nl/public/facilities/f155-01/index.html

SECTION II. LITERATURE SEARCH RESULTS

KEYWORDS

The runway incursion literature search was conducted using the keywords listed below. The results of this search are included in the following section.

Aeronautics
Aircraft
Aircraft accidents.
Airlines
Airplane
Aviation
Aviation Accident Investigation
Cockpit
Collision
Collision avoidance
Conflict
Conflict
Flight
Ground control
Helicopter
Human
Incursion
Incursions and runway
Landing
Near collisions
Near misses
Operator
Performance
Pilot
Runway
Runway incursion
Safety measures
Signage
Take-off
Taxiing
Transgression
Transgression

KEY AUTHORS

Hockaday, Stephen
McKenna, James
Sparaco, Pierre
Smith, Kip
Fiorino, Frances
Phillips, Edward

DATABASES SEARCHED{ TC "2. DATABASES SEARCHED" \F C \L "1" }

The following databases were searched. Their results are presented in this volume.

Aerospace Database
Applied Science and Technology Abstracts (1983-present)
Dissertation Abstracts Online
National Technical Information Service (NTIS)
Newspaper Abstracts (1989-present)
PSYCHinfo
SciSearch
Transport Research Information Service (TRIS)
WorldCat

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Most of the documents identified in this search can be obtained through local resources, such as city, university, or company libraries or through inter-library loan programs sponsored by these libraries. However, some of these documents may be available only through special organizations, such as the Defense Technical Information Center (DTIC), National Technical Information Service (NTIS), or other commercial document vendors.

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http://www.dtic.mil/iac/cseriac/cseriac.html

CITATIONS

Aarons, R. N (1992). When Good Intentions Lead to Bad Ends. *Business and Commercial Aviation, 70,* 76+(0191-4642).

Aarons, R. N.(1995). Making Communication Work. 441. *Business & Commercial Aviation, 76,* 82 (0191-4642).

Abstract: The initial findings of the National Transportation Safety Board (NTSB) experts investigating a fatal runway collision in November 1994 include a recommendation for air traffic controllers and pilots to improve voice communications immediately. The investigators noted that the pilot, after receiving clearance to taxi, did not read back his assignment during any subsequent transmission, nor was he required to do so. The NTSB has recommended to the Federal Aviation Administration that air traffic control procedures be amended to require that controllers receive full acknowledgment of runway assignment and any clearance associated with the runway assignment.

Aarons, R. N.(1997). Sad Day at Quincy. *Business & Commercial Aviation,81,* 82(0191-4642).

Abstract: The National Transportation Safety Board (NTSB) has called upon flight instructors to emphasize careful scanning techniques during training and biennial flight reviews. This recommendation is a result of the NTSB's investigation into the November 1996 fatal runway intersection collision at Quincy, Illinois. The accident claimed the lives of the 2 occupants of a corporate King Air A90 and the 2 crewmembers and 10 passengers of a United Express Beech 1900C. According to the NTSB, the probable cause of the collision was the failure of the A90 pilots to effectively monitor the CTAF or to properly scan for traffic.

Abbink, F. J. (1995). *Avionics System Approach for Future Civil Aviation* (Report No. PB97-193247. NLR-TP-95286-U). Netherlands: National Aerospace Lab.

Abstract: Air transport will further expand in the next two decades. New airliners, runways, passenger terminals and computer assisted or automated Air Traffic Control (ATC) systems will be necessary to accommodate the increasing traffic. The new ATC systems will require computer assisted planning, digital datalinks between ATC computers and aircraft computer systems and improved worldwide communication, navigation and surveillance systems (partly satellite-based). To further improve safety levels, apart from improved ATC infrastructure, training and procedures, also an enhanced 'safety net' of warning systems to alert the pilot for imminent ground collision, windshear and mid-air collision will have to be developed. Finally the Man-Machine Interface (based on Synthetic and Enhanced Vision) will have to be developed to provide improved situational awareness and enable quick interpretation of and reaction to warning signals as well as to allow safe operation to and from minimally equipped airports.

Air Transportation (1993). *Aerospace America, 31,* 26-7 (0740-722X).

Abstract: Part of a review of the aerospace industry in 1993. Many U.S. airlines are downsizing or eliminating their hubs. The elimination of hubbing may be accompanied by other changes, such as the return of interlining, in which carriers must exchange passengers to get them to their final destination. Airport surface incidents and runway incursions continue to be a serious threat to surface operations and airport safety. The

Federal Aviation Administration is implementing enhanced ground surveillance radar and conflict alerting systems to assist air traffic control. In addition, NASA is sponsoring research into the development of technologies to produce environmentally acceptable and economically feasible High Speed Civil Transport. .

Allgood, G. O., Kennedy, R. S., Vanhoy, B. W., Lilienthal, M. G., & Hooper, J. M. (1987). The Effects of Very-Low Frequency Vibrations on Simulator Sickness. ***Aviation Space and Environmental Medicine, 58*****(5), 504.**

Amar, M. J., Hansman, J., Vaneck, T. W., Chaudhry, A. I., & Hannon, D. J. (1995). A Preliminary Evaluation of Electronic Taxi Charts with GPS Derived Position for Airport Surface Situational Awareness. In R. S. Jensen and L. A. Rakovan (Eds.) ***Proceedings of the Eighth International Symposium on Aviation Psychology, Volume 1*** **(499-504).**

Abstract: A study was conducted to test the effect on airport surface situational awareness of GPS derived position information depicted on a prototypical electronic taxi chart display. The effect of position error and position uncertainty symbology were also tested. Situational awareness was assessed by a series of probe questions about location on the airport. Four levels of GPS position accuracy were tested ranging from 5 to 100 meters. Two types of position uncertainty symbology were also tested. The variable radius uncertainty circle displayed a worst case system accuracy of 100 meters. Situational awareness, as indicated by probe question response accuracy, did not significantly increase over the 'no GPS' case at 100 m accuracy when GPS worst case position uncertainty was displayed on the electronic taxi chart. Situational awareness did increase however, when better GPS accuracies were presented. In addition, response time was also found to improve with the presence of aircraft position information.

Andre, A. D. (1996). ***Operational Issues During Low-Visibility Taxi Operations: A Field Study*** **(Report No. NASA-CR-201010. NAS 1.26:201010. NIPS-96-50755). Monte Sereno, CA: Western Aerospace Labs, Inc.**

Abstract: Low-visibility conditions present a host of problems for the National Airspace System. While many modem aircraft are equipped with automation that allows them to land under low-visibility conditions, there is no such corresponding technology to aid the pilots in taxiing the aircraft from runway to gate, or vice versa. Consequently, flight throughput and sequencing is severely constrained, especially at the major airports. Current efforts within NASA, the FAA, and the commercial aviation industry are aimed at developing technologies to increase the efficiency and safety of taxi operations under low-visibility conditions. Based on cockpit observations, pilot interviews, and pilot-controller communications, this paper presents an analysis of current problems experienced by pilots during the taxi operations, and presents their views on key issues related to the introduction of electronic taxi map displays in the cockpit. The data were collected by the author while serving as a flight deck observer aboard thirty-five commercial carrier flights. The implications of these data for the justification and design of advanced cockpit displays for taxi operations are discussed, and the importance of including pilot experiences, opinions, and attitudes in the research and design process is stressed.

Anonymous (1991). Second Near Collision Spurs F.A.A. Inquiry. ***New York Times Current Events Edition*****.**

Abstract: A second near-miss of a Midway Airlines craft at Chicago's Midway Airport on Oct 3, 1991 has prompted an inquiry, the FAA said.

Anonymous (1995). Board Considers Crash on Runway Preventable. ***New York Times Current Events Edition*****.**

Abstract: A runway collision between a jetliner and a small plane in St Louis in Nov 1994 that killed two people might have been prevented if a planned radar system had been operating, the NTSB has found.

Anonymous (1996). Small Airports' Big Question: Do Costly Towers Buy Safety? ***The Los Angeles Times,*** **(0458-3035).**

Abstract: An editorial discusses issues of safety at small airports in the wake of the Nov 19, 1996 collision of two planes on the runway of a small Illinois airport.

Anonymous (1998). A Slip-up Can Mean Disaster. ***The Los Angeles Times,*** **(0458-3035).**

Abstract: The Federal Aviation Administration was right last week to order the retraining of 10,000 air traffic controllers by the end of the month. The action was triggered by a near disaster at New York's La Guardia Airport April 3. In that incident, a U.S. Airways jet ordered to abort a landing came within 20 to 40 feet of an Air Canada jet that was taking off. That near collision is under investigation, but officials have said that the controller should have recognized the situation sooner and issued the order to abort the landing much earlier. There has also been an increase in so-called "operational errors" by controllers in which aircraft are allowed to enter a safety bubble of five miles of horizontal separation or 1,000 feet above or below an aircraft. But the size of the bubble also means that collisions are not necessarily imminent.

Anonymous (1998). U.S. Describes Near Collision on a Runway at La Guardia. ***New York Times,*** **(0362-4331).**

Abstract: Federal aviation officials say an air traffic controller made an "operational error" that caused a Boeing 737 to fly over and land dangerously close to a private plane at La Guardia Airport last week. A spokesman for the air traffic controllers' union agreed that the controller erred but said a Federal Aviation Administration manager was also to blame because he went home before clearing a closed runway, leaving one of two controllers on duty to handle it. The F.A.A. said in a statement yesterday that the private plane, a King Air BE-90, was on runway 31 waiting to depart about 10:30 P.M. when US Airways Flight 1290 was given permission to land on the same runway.

Anonymous (2000). Ground Traffic Control. ***Times - Picayune*****.**

Abstract: Forget about what might happen at 35,000 feet, some of the riskiest moments spent on an airplane might well be when it's still on the runway. That's why the Federal Aviation Administration is focusing on runway hazards, launching a yearlong study of close calls at airports and increasing training for pilots as well as air traffic controllers.

Anonymous (2000). Near Misses Mount Along With FAA's Broken Promises. ***USA Today,*** **(0734-7456).**

Abstract: Too many times last year at too many of the nation's busiest airports, huge passenger jets taking off or landing suffered horrifying near misses. Last April, at Chicago's O'Hare, a Korean Air 747 was forced to lift off abruptly to avoid another 747 that had wandered onto its runway. At Los Angeles International in November, a departing United 757 missed by 100 feet an AeroMexico jet that had just landed. Since 1993, runway near misses have climbed by 73%. Many federal safety experts now rank these "runway incursions" as the most serious threat to airline safety. Yet since 1991, the Federal Aviation Administration has been promising preventive measures and failing to

put them in place.

Armstrong, H. B. & Roske-Hofstrand, R. (1989). Multi-media authoring - Instruction and training of air traffic controllers based on ASRS incident reports. In *International Symposium on Aviation Psychology, 5th, Proceedings. Volume 2* (pp. 896-901). Columbus, OH: Ohio State University.

Abstract: This paper discusses the use of computer-assisted instructions and flight simulations to enhance procedural and perceptual motor task training. Attention is called to the fact that incorporating the accident and incident data contained in reports filed with the Aviation Safety Reporting System (ASRS) would be a valuable training tool which the learner could apply for other situations. The need to segment the events is emphasized; this would make it possible to modify events in order to suit the needs of the training environment. Methods were developed for designing meaningful scenario development on runway incursions on the basis of analysis of ASRS reports. It is noted that, while the development of interactive training tools using the ASRS and other data bases holds much promise, the design and production of interactive video programs and laser disks are very expensive. It is suggested that this problem may be overcome by sharing the costs of production to develop a library of materials available to a broad range of users. (I.S.)

Ballin, M. G., & Erzberger, H. (1996). *An analysis of landing rates and separations at the Dallas/Fort Worth International Airport* (Report No. N96-31262/4. NAS 1.26:110397; A-961649; NASA-TM-110397). Moffett Field, CA: National Aeronautics and Space Administration.

Abstract: Advanced air traffic management systems such as the Center/TRACON Automation System (CTAS) should yield a wide range of benefits, including reduced aircraft delays and controller workload. To determine the traffic-flow benefits achievable from future terminal airspace automation, live radar information was used to perform an analysis of current aircraft landing rates and separations at the Dallas/Fort Worth International Airport. Separation statistics that result when controllers balance complex control procedural constraints in order to maintain high landing rates are presented. In addition, the analysis estimates the potential for airport capacity improvements by determining the unused landing opportunities that occur during rush traffic periods. Results suggest a large potential for improving the accuracy and consistency of spacing between arrivals on final approach, and they support earlier simulation findings that improved air traffic management would increase capacity and reduce delays.

Bandon, C., Baker, K., Blasier, J., Bouchard, F., & Coyne, F. (1997). *Low-Cost ASDE Evaluation Report: Raytheon ASDE (Phase 2) Radar at MKE (M3625/18CPX-12)* (Report No. NASA no. 19980018858. AD-A331597. DOT-VNTSC-FAA-97-14). Washington, D.C.: Federal Aviation Administration.

Abstract: The Federal Aviation Administration's (FAA) Runway incursion Reduction Program's Terminal Surveillance product Team has tasked the John A. Volpe National Transportation Systems Center to install and evaluate low cost Airport Surface Detection Equipment (ASDE) radar systems to aid air traffic controllers, during low visibility conditions, to detect surface radar targets and sequence aircraft movement on active runways. This document publishes test results of the Raytheon ASDE installed at Milwaukee's General Mitchell Airport. The low cost radars are being assessed for their ground surveillance potential for widespread use at smaller facilities. The report includes radar components and specifications, installation summary, functional and operational evaluations, system performance analysis, and recommendations. Test results show that,

in low visibility conditions, the system enhanced controllers' situational awareness, detected and displayed targets, aided movement area clearance, and enabled controllers to confirm pilot's reported positions on the surface and their compliance with tower instructions. The ASDE's positive initial acceptance and low cost make it a sound option for small airports seeking effective ground surveillance radar.

Batson, V. M., Harris, R. L., & Hunt, P. (1994). Navigating the airport surface - Electronic vs. paper maps. In: *Proceedings of the AIAA/IEEE Digital Avionics Systems Conference, 13th, Phoenix, AZ, Oct. 30-Nov. 3, 1994* (p. 515-520). New York: Institute of Electrical and Electronics Engineers, Inc.

Abstract: Recent advances in the Differential GPS and ground/aircraft data links provide a basis for the generation of an accurate cockpit navigational map display including data-linked ATC-cleared ground routes. Such an electronic map may have the potential to improve pilots' situation awareness and taxi performance and thereby lessen runway incursions. The objective of this simulator study was to assess the potential improvements in these areas when using an advanced electronic map (compared to using today's paper map) under two outside scene visibility levels. Results showed average taxi speed increased under both good and poor visibilities by as much as 24 percent, due in part to eliminating the time used for orientation with the paper map. Pilots made only one-third as many errors as well and commented that they believed that the electronic map gave them better awareness.

Begault, D. R. (1993). Head-up auditory displays for traffic collision avoidance system advisories: a preliminary investigation. *Human Factors,* 707-717.

Abstract: Evaluated the advantage of a head-up auditory display in a preliminary experiment to measure and compare the acquisition time for capturing visual targets under 2 auditory conditions: standard 1-earpiece presentation and 2-earpiece 3-dimensional (3D) audio presentation. 12 commercial airline crews were tested under full mission simulation conditions in an advanced concepts flight simulator. Scenario software generated visual targets corresponding to aircraft that would activate a traffic collision avoidance system (TCAS) aural advisory. The spatial auditory position was linked to the visual position with 3D audio presentation. Results show that Ss using a 3D auditory display acquired targets approximately 2.2 sec faster than did Ss who used 1-earpiece headsets. However, there was no significant difference in the number of targets acquired.

Begault, D. R., & Pittman, M. T. (1996). Three-dimensional audio versus head-down traffic alert and collision avoidance system displays. *International Journal of Aviation Psychology,* 79-93.

Abstract: Measured and compared the acquisition time for capturing visual targets under 2 conditions: standard head-down Traffic Alert and Collision Avoidance System (TCAS) display and a 3-dimensional (3-D) audio TCAS. 10 2-person flight crews (1st officers and captains) were tested under full-mission simulation conditions at the NASA-Ames Crew-Vehicle Systems Research Facility Advanced Concepts Flight Simulator. The technology used for the 3-D TCAS allows a stereo headphone user to potentially localize a sound at any externalized position in 3-D auditory space. Scenario software generated targets corresponding to aircraft that activated a 3-D aural advisory (head-up auditory condition) or a standard, visual-audio TCAS advisory (map display with monoaural alert). Results showed a significant difference in target acquisition time between the 2 conditions, favoring the 3-D audio TCAS condition by 500 ms.

Berbaum, K. S., Kennedy, R. S., & Hettinger, L. J. (1991). Visual Tasks in Helicopter Shipboard Landing. *Applied Ergonomics, 22*(4), 231-239.

Abstract: The purpose of this research was to identify visual scene content important in helicopter shipboard landings, particularly in the hover phase, for further study in a research simulator. A second purpose was to illustrate the use of a methodology (Protocol Analysis) which may hold promise for many areas of human factors research. Discussions with pilots, reviews of relevant Naval Aviation Training and Operational Procedures (NATOPS) manuals and observation of simulated helicopter shipboard landings suggested that the visual elements required in helicopter shipboard landings may depend upon whether experienced or inexperienced pilots are flying, a simulator or an aircraft is flown, the environment is day or night, or the pilot seeks to acquire or maintain a skill level. A scenario involving an experienced pilot flying dusk/night approaches in a simulator was intensively studied. As he flew each approach, the pilot dictated real-time verbal protocols of his visual and control activities. These protocols were subsequently partitioned by the authors into nine phases defined in terms of range or altitude from the ship, and the visual tasks required in each segment were described. An outcome of this analysis was a list of visual cue augmentations that may be useful for providing augmented feedback in training.

Berman, E. (1998). Infrared augmentation system for collision avoidance on airport surfaces. In: *Signal processing, sensor fusion, and target recognition VII; Proceedings of the Meeting, Orlando, FL, Apr. 13-15, 1998* (p. 280-289.), Bellingham, WA: Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Vol. 3374).

Abstract: This paper describes the testing of IR cameras and operational concepts to improve detection and tracking of targets on airport surfaces. Three different cameras were tested during summer and winter months and during inclement weather. Two operational concepts were tested at Dulles International Airport. A prototype image processing system is described that extracts target coordinates from camera video output and passes them to an AMASS simulator for fusion with radar and other target tracking data. All three cameras evaluated were able to detect and recognize a variety of targets on a runway surface, including humans, vehicles, and small and large airplanes. The range to detection and recognition varies with each camera's instantaneous FOV, thermal sensitivity, atmospheric conditions, and operating conditions. Each camera was found to meet specific FAA requirements in unique ways. (Author)

Brelis, M. (1996). Competitors Unite on Safety Efforts at Logan. *Boston Globe,* (0743-1791).

Abstract: Logan International Airport in Boston is the first major airport in the US where mechanics from different airlines and freight carriers meet once a month with airport officals to exchange information on topics ranging from runway incursions to the dangers to mechanics of the massive engines of the new Boeing 777 jumbo jet.

Brelis, M. (1998). In Computer Outage, 2 Jets Almost Hit Controllers in N.H. Blame Malfunction. *Boston Globe,* (0743-1791).

Abstract: A computer that Boston Center air-traffic controllers rely on to provide them with identifying data about the aircraft they direct malfunctioned Sunday night, resulting in two Europe-bound jumbo jets nearly colliding off Long Island, air-traffic controllers said. Controllers at the Boston Center in Nashua, N.H., who have faced repeated computer outages in the past year, were literally in the dark about the near collision until the pilot of British Caledonia Flight 5199 said he was going to file a report upon landing, controllers said. The on-board computer systems on the two airplanes, known as TCAS, for Traffic Collision Avoidance System, alerted each flight crew of the approaching

aircraft. The Delta jet, Flight 66, was told by its TCAS to climb it went to 33,600 feet and the L-1011 plane was told to descend. It went to 32,700 feet. The two planes passed within 1.07 miles of each other, according to the FAA.

Bryant, A. (1994). Fatal Runway Collision Under U.S. Inquiry. ***New York Times Current Events Edition*****.**
Abstract: The NTSB on Nov 23, 1994 was investigating why a twin-engine propeller plane taxied into the path of a Trans World Airlines jet taking off the day before from St Louis, resulting in a collision that killed the two pilots aboard the smaller plane.

Bussolari, S. R. (1991). Real-Time Control Tower Simulation for Evaluation of Airport Surface Traffic Automation. In R. S. Jensen (Ed.) ***Proceedings of the Sixth International Symposium on Aviation Psychology, Volume 1*** **(pp. 502-507).**
Abstract: High fidelity, real-time aircraft simulation has been a valuable tool for the human factors evaluation of flight deck automation, but no equivalent simulation has been available for the air traffic control tower (ATCT) environment. The capacity, flexibility, and data collection requirements placed on a research simulation preclude the use of existing tower training systems. Using a network of computer workstations, an ATCT real-time simulation has been developed that is capable of reproducing the traffic environment found at major airports. The simulation will be used for preliminary evaluation of the impact of automation upon tower controller workload and situational awareness.

Butterworth-Hayes, P. (1992). Shedding light on runway incursions. ***Jane's Airport Review*** **(pp. 49-52).**

Capezzuto, V., Olster, D., Curry, M., & Pendergast, S. (1998). Runway Incursion Reduction Program (RIRP) surveillance system, NASA/FAA Atlanta demonstration. In: ***DASC - AIAA/IEEE/SAE Digital Avionics Systems Conference, 17th, Bellevue, WA, Oct. 31-Nov. 7, 1998, Proceedings. Vol. 2*** **(pp. F31-1 to F31-8). Piscataway, NJ: Institute of Electrical and Electronics Engineers, Inc.**
Abstract: This paper describes the performance of the RIRP surveillance system, as well as the impact of the system on current FAA airport services. The centerpiece of the demonstration surveillance system was the Airport Movement Area Safety System (AMASS). The multiple surveillance subsystems were fed into the prototype AMASS to be 'fused' into an optimal report. Data fusion allows the integration of two or more sensors to provide a position and identification report that is of higher integrity than any one sensor would be alone. This enhanced report in turn could improve the safety logic calculation within AMASS. The surveillance system demonstrated the ability to provide enhanced and seamless surveillance, identification of targets, and information sharing with users of the airport. Detection coverage, track continuity, and target identification improved as a result of the system. The surveillance system did not impair the current NAS system from maintaining surveillance on aircraft.

Carley, W. M. (1999). Duck and Cover up: FAA's Scary Finding: Controllers Sometimes Conceal Close Calls Unreported Incidents Suggest Some Fear Punishment for `Operational Errors' `His Throat Was in His Belly'. ***Wall Street Journal,*** **(0099-9660).**
Abstract: As an Air Canada jet was taking off at LaGuardia Airport on one runway, a USAirways plane was approaching to land on an intersecting runway. Fearing a collision, a tower controller radioed: "USAir nine twenty, go around" to make a second approach.

The US Airways jet pulled up, but then the co-pilot at the controls spotted the airborne Air Canada jet crossing right in front. "Look there," the co-pilot shouted to the captain as he ducked his jet under the Air Canada plane. The jets missed by 20 feet, so close that the US Airways captain said in a subsequent report that he feared his tail would slice through the Air Canada plane passing overhead. Nevertheless, this near-collision April 3 last year wasn't reported by either the air-traffic controller or his supervisor to Federal Aviation Administration officials. It was only after the US Airways pilots complained to the National Transportation Safety Board that the seriousness of the event began to emerge. In most cases, it is pilot reports that disclose errors that controllers haven't reported to FAA superiors. FAA controllers or supervisors are supposed to report operational errors to facility managers immediately, and the managers must notify FAA regional headquarters within three hours of the incident.

Carley, W. M., & Pasztor, A. (1999). Pilot Error: Korean Air Confronts Dismal Safety Record Rooted in Its Culture Military-Civilian Hierarchy Mars Cockpit Teamwork; Rote Training Hurts, Too Fatal Confusion Over Guam. *Wall Street Journal* (0099-9660).

Abstract: Delta Air Lines, Air France and Air Canada, which through code-sharing pacts had been booking passengers on Korean Air, suspended those agreements in April. In a confidential report last year to Korean Air's top management, a team of current and former Delta pilots brought in to advise the Korean airline said that unless it changed an insular cockpit culture, it was likely to suffer a "steady increase in the number of safety-related incidents and accidents," and without dramatic improvements, a loss of public trust could even lead to "the death of the airline." Interviews with regulators and current and former Korean Air pilots, as well as documents and air-traffic tapes obtained from the Federal Aviation Administration, show the extent of Korean Air's problems in the cockpit. They involve Korea's authoritarian culture, reflected in a hiring and promotion policy that favors former military fliers over civilians. Too often, the effect has been friction that hampers the pilot teamwork needed to fly Western-built jets. A rigid training program and weak English make it still harder for some Korean Air pilots to deal with air controllers and cope with emergencies. And despite the criticism heaped on Korean Air pilots, "some are really sharp," says Rick Anderton, a former Eastern Airlines pilot who later flew for Korean Air. One pilot's quick reactions recently averted a runway collision at Chicago when a taxiing jumbo jet from Taiwan's China Airlines mistakenly began to enter a runway from the right side, in front of a Korean Air 747 cleared for takeoff. Lifting off at 200 miles an hour, the Korean Air captain adroitly banked left, missing the nose of the China Air jet by 75 feet.

Caruso, C. (1992). *Global positioning system runway incursion program static ground tests* (Report No. DOT/FAA/CT-TN91/44. AD-A257051). Atlantic City, NJ: Federal Aviation Administration.

Abstract: Described here are the ground tests of the Global Positioning System (GPS) in the terminal area at the Atlantic City International Airport. The purpose of the Runway Incursion Program is to investigate the application of GPS as a navigation aid to allow the pilot to safely transverse airport taxiways and runways under poor visibility conditions. The primary objective of the tests was to resolve the critical issue of differential GPS accuracy as a function of the differential update rate.

Cassell, R., & Evers, C. (1998). Development of airport surface surveillance performance requirements. In: *DASC - AIAA/IEEE/SAE Digital Avionics Systems Conference, 17th, Bellevue, WA, Oct. 31-Nov. 7, 1998, Proceedings. Vol. 2* (p. F32-1 to F32-7),

Piscataway, NJ: Institute of Electrical and Electronics Engineers, Inc.
Abstract: There are a number of new technologies being assessed for performing surveillance of aircraft and vehicles on the airport surface. The reason for increased interest in such technologies is to address the problem of runway incursions and the associated risk of collisions. Technologies are under development to assist in conflict detection and collision avoidance on the airport surface. Activities are under way to develop a set of performance standards by which the adequacy of these technologies can be judged. This paper presents a summary of recent efforts by ICAO and RTCA to develop surface surveillance performance requirements. This includes proposed requirements for four key parameters: integrity, continuity, accuracy, and availability. The paper also describes the methodologies being used to develop the requirements.

Castaldo, R., Evers, C., & Smith, A. (1996). Improved location/identification of aircraft/ground vehicles on airport movement areas - Results of FAA trials. In: *Technology and operations: Partnership for success in navigation; Proceedings of the Inst. of Navigation National Technical Meeting, Santa Monica, CA, Jan. 22-24, 1996* (p. 555-562), Alexandria, VA: Institute of Navigation.
Abstract: This paper describes the development, implementation, and testing of the Airport Surface Target Identification System (ATIDS) and presents results of initial trials. The overall goal of the research is to implement cost-effective surveillance systems that can reduce the risk of runway incursions. A runway incursion occurs when a vehicle strays onto an active runway, usually caused by human error. Approximately 200 runway incursions occur each year in the United States and several serious accidents involving loss of life have occurred. One of the FAA initiatives to address this safety issue is ATIDS. ATIDS provides the location and identification of all aircraft and vehicle traffic on the airport movement area and in selected ramp and gate areas. ATIDS is based on SSR technology and is an enhancement to current airport primary surveillance equipment which is primarily the Airport Surface Detection Equipment/Airport Movement Area Safety System.

Chamberlin, R., Drew, C., Patten, M., & Matchette, R. (1995). Airport Ramp Safety and Crew Performance Issues. In R. S. Jensen and L. A. Rakovan (Eds.) *Proceedings of the Eighth International Symposium on Aviation Psychology, Volume 1* (489-494).
Abstract: This study examined 182 ramp operations incident reports from the Aviation Safety Reporting System (ASRS) database, to determine what factors influence ramp operation incidents. It was found that incidents occurred more often during aircraft arrival operations than during departure operations; incidents occurred most often at the gate stop area, less so at the gate entry/exit areas, and least on the ramp fringe area; and reporters cited fewer incidents when more ground crew were present. The authors offer suggestions for both airline management and flight crews to reduce the rate of ramp incidents.

Cockburn, D. (1998). Aircraft collision risks at the start of the 21st century. *Journal, 51*(3), 439-444.

Collogan, D. (1994). The High Price of a Crisis. *Business and Commercial Aviation, 59,* 109.

Conroy, M. T. (1991). Eight Die in Aircraft Collision on Detroit Runway. *NFPA Journal, 85,* 69+.

Cross, S. E. (1985). Computer understanding of air traffic control displays. *IEEE*

***Transactions on Systems, Man, & Cybernetics,* 133-135.**
Abstract: Describes an expert computer system that applies strategies to manipulate the conflict structure (the representation of displayed aircraft conflict data) and define less complex subproblems of air traffic control displays. The conflict structure is a global, semantic representation of the human air traffic controller's visual field as restricted to the collision-avoidance task. The computer can represent and interpret the data in a manner similar to that of experienced controllers. Unneeded details are suppressed and replaced with a semantic description. (7 ref) ((c) 1999 APA/PsycINFO, all rights reserved)

Cushing, S. (1994). *Fatal Words: Communication Clashes and Aircraft Crashes*. Chicago: The University of Chicago Press.
Abstract: On March 27, 1977, 583 people died when KLM and Pan Am 747s collided on a crowded, foggy runway in Tenerife, the Canary Islands. The cause, a miscommunication between a pilot and an air traffic controller. The pilot radioed 'We are not at takeoff', meaning that the plane was lifting off, but the tower controller misunderstood and thought the plane was waiting on the runway. The author explains how miscommunication has led to dozens of aircraft disasters, and he proposes solutions for preventing them. He examines ambiguities in language and other causes of miscommunication between pilots and air traffic controllers and looks at instances when a pilot or tower controller slips from technical aviation jargon into colloquial English, when a pilot inadvertently 'tunes out' repeated instructions, when radios are misused, when a word is used that has different meanings, and when different words are used that sound alike. For example, he shows how a confusion involving 'to' and 'two' led to a fatal crash at a Southeast Asian airport. To remedy these problems the author proposes, for the short term, a visual communication system to supplement voice communication, one that would include a visual touchscreen interface. The technical details of a visual touchscreen prototype are included in an appendix. For the longer term, the author outlines an intelligent voice interface to filter conversations for potential confusions and provide real-time feedback to help clear up confusing language.

Damos, D. L., Bittner, A. C., Kennedy, R. S., & Harbeson, M. M. (1981). Effects of Extended Practice on Dual-Task Tracking Performance. *Human Factors, 23*(5), 627-631.

David, H. (1997). *Radical Revision of En-Route Air Traffic Control* (Report No. PB97-159388. EEC-307). Bretigny-sur-Orge (France):EUROCONTROL Experimental Centre.
Abstract: A study of the En-route Air Traffic Controllers' Interface with the ATC system led to wider consideration of the display and handling of ATC information for en-route air traffic. Initial consideration of the 'surface ergonomics' led to an in-depth consideration of the proper allocation of tasks between the controller and the system, and of the optimal distribution of information flow, employing current available technology. This leads to a proposal for a radical revision of En-route Air Traffic Control, the consequences of which are briefly considered.

Davis, R. (1997). Disasters Wait to Happen on Busy Runways. *USA Today,* (0734-7456).
Abstract: As his Boeing 737 rumbled along the runway for takeoff from San Francisco International Airport, the United Airlines captain saw a small plane appear through the rain in front of his jet. "Aircraft on the runway!" he called to his co-pilot. The co-pilot quickly pulled back on the control yoke and managed to take off before the two planes hit. The pilot says his passenger jet missed the private plane by less than 50 feet on that

day last June. Those who watch the nation's air-safety system say a runway collision is waiting to happen. To prevent disaster, safety experts are at work on a variety of things from installing entrance lights that tell pilots when a runway is in use to looking for ways that controllers and pilots can avoid misunderstandings.

Deckert, J. (1992). Integrating TCAS into the airspace management system. In: *IEEE PLANS '92 - Position Location and Navigation Symposium, Monterey, CA, Mar. 24-27, 1992, Record* (A93-10976 01-04).
Abstract: It is suggested that TCAS-II (Traffic Alert/Collision Avoidance System II) will evolve from its limited collision-avoidance-only role to become an integral part of the airspace management system. Benefits will be cooperative air traffic procedures, reduced separations, and independent routings. (I.E.)

DeLucia, P. R. (1995). Effects of pictorial relative size and ground-intercept information on judgments about potential collisions in perspective displays. *Human Factors,* 528-538.
Abstract: (Investigated factors influencing the ability of 20 Ss to judge whether 2 objects that approached each other in midair would collide, using perspective displays. When objects were different sizes, observers often did not detect imminent collisions. Errors decreased with equal-sized objects or ground-intercept information. Results suggest that judgments about collision in perspective displays (e.g., three-dimensional displays of aircraft) can be enhanced by minimizing ambiguities created by pictorial relative size cues. ((c) 1999 APA/PsycINFO, all rights reserved)

Dietz, D. (1997). Airport Runway Mishaps Jump 16% in 6 Months / Chicago Near-Miss Among the 137 Incidents. *San Francisco Chronicle*.
Abstract: If the pattern continues, 1997 would be the fourth straight year of increases in so-called runway "incursions." A revised total of 284 incidents were reported last year, the most since the Federal Aviation Administration began keeping accurate records a decade ago. Runway problems, and the FAA's spotty record in dealing with them, have been the subject of a continuing series of articles in The Chronicle. Key safety initiatives ranging from a collision-warning system for airport control towers to improved plane lighting are either badly delayed or in limbo. "The continued increase in runway incursions is troubling," said Barry Sweedler, director of safety recommendations at the National Transportation Safety Board, which has been imploring the FAA for years to deal more aggressively with airport mishaps. "These incidents should serve as an early warning system."

Dietz, D. (1997). Peril on the Nation's Runways / FAA Slow to Act on Crashes and Close Calls on the Ground. *San Francisco Chronicle*.
Abstract: US aviation officials have minimized for years the danger of airliner collisions on the ground, despite five fatal crashes since 1990 and a steady increase in the number of close calls. At a time when the FAA is concentrating on preventing midair collisions, pilots, accident investigators and air traffic controllers say the nation's most overlooked aviation hazard is on the runways. Last Monday, the FAA itself had a close call when a Learjet from the agency's fleet almost taxied into the path of a commuter plane taking off at Washington, D.C.'s National Airport. The commuter plane cleared the FAA jet by 100 feet. Runway "incursions" the FAA term for planes and airport vehicles straying off course and causing a hazard are up more than 50 percent over the past four years. And the 287 incidents reported in 1996 were the most since the government began keeping accurate figures 10 years ago, according to the FAA. San Francisco International Airport

typically has a high number of incidents and last year had five, a problem linked to extensive traffic on runways. Among the busiest airports, Cleveland, St. Louis and Newark had the highest number of close calls last year. The FAA has taken some steps to improve runway safety, under prodding from the NTSB and others. But a Chronicle investigation based on federal aviation reports and interviews with accident investigators and other safety experts revealed an airport traffic control system still plagued with serious flaws including:

Dietz, D. (1998). FAA Asked to Boost Safety on Runways / Industry Group Calls for Improvements. *San Francisco Chronicle*.
Abstract: An industry advisory group to the Federal Aviation Administration has urged a series of safety improvements for airport runway operations, putting new pressure on the agency to control a rising number of collision hazards. The proposals, which range from more precise tower-pilot communications to bolstered runway markings, grow out of Chronicle articles that questioned the FAA program dealing with near-misses and other runway lapses. The study group's report is the second major appeal in recent months for FAA runway action. In November, an audit by the Department of Transportation's inspector general found significant FAA lapses and urged a shakeup in the runway program.

Dietz, D. (1999). Safety Plan for Runways Called a Flop / Too Many Near Misses -- Report Criticizes FAA. *San Francisco Chronicle*.
Abstract: A Federal Aviation Administration program to avoid accidents and close calls on runways has flopped, a government oversight report said yesterday. The report, by the Department of Transportation's inspector general, said the number of "runway incursions" remains at a high level because the FAA has been too slow to fight the hazard. It was the second major analysis this year to criticize the FAA's handling of a problem that a White House report identified in 1998 as one of the most pressing aviation dangers.

Donohue, G. (1995). Vision on aviation surveillance systems. In: *IEEE International Radar Conference, Alexandria, VA, May 8-11, 1995, Record* (p. 1-4), New York: Institute of Electrical and Electronics Engineers, Inc.
Abstract: The FAA's future aviation surveillance systems fall into four categories: Automatic Dependent Surveillance will be used in the oceanic environment; ADS-Broadcast (ADS-B) will be used in the domestic en route environment; ADS-B will be used with a secondary radar backup in the terminal area; and ADS-B will be used with primary radar backup within the Airport Surface Traffic Automation system on the airport's surface environment. Two other systems introduced in this paper are Cockpit Display of Traffic Information and Traffic Advisory and Collision Avoidance System (TCAS). All these systems will use navigational signals emitted by the GPS constellation of satellites. This paper is a visionary look at these future systems.

Dornheim, M. A. (1991) L.A. Tower Tapes Show Controller Unaware of Aircraft Holding on Runway. *Aviation Week & Space Technology, 134*(14), 61-3(0005-2175).
Abstract: The FAA has released tower tapes concerning the February 1 runway collision at Los Angeles International Airport. The tapes do not contradict the testimony of the local controller involved in the collision. She had testified that she mistook one commercial turboprop for another. The accident is chronicled, and a transcript of the tape is provided.

Doyle, T., & McGee, S. (1998). ***Air Traffic and Operational Data on Selected US Airports with Parallel Runways*** **(Report No. NASA no. 19980197296. NASA/CR-1998-207675. NAS 1.26:207675).**
Abstract: This report presents information on a number of airports in the country with parallel runways and focuses on those that have at least one pair of parallel runways closer than 4300 ft. Information contained in the report describes the airport's current operational activity as obtained through contact with the facility and from FAA air traffic tower activity data for FY 1997. The primary reason for this document is to provide a single source of information for research to determine airports where Airborne Information for Lateral Spacing (AILS) technology may be applicable.

Drouilhet, P. R. Jr. (1989). Air traffic control development at Lincoln Laboratory. ***The Lincoln Laboratory Journal 2*****, 331-344.**
Abstract: Advances in air traffic control aimed at improving surveillance, communications, collision avoidance, and severe-weather sensing are examined. Consideration is given to the discrete address beacon system, Mode S, MLS, GPS, the Next-generation weather radar, moving target detection, the traffic advisory and collision avoidance system, and the parallel and converging runway monitor. Research in the area of data-link services are discussed. Current studies involve the development of techniques and algorithms to improve air traffic management.

Duke, T. (1997). Preventing runway incursions. Part 1. Airline pilots, given immunity, speak out about runway problems and suggest solutions to prevent accidents on the runway. ***Air Line Pilot, 66*****(6), 10-13.**
Abstract: SUBTITLE: AIRLINE PILOTS, GIVEN IMMUNITY, SPEAK OUT ABOUT RUNWAY PROBLEMS AND SUGGEST SOLUTIONS TO PREVENT ACCIDENTS ON THE RUNWAY

Duke, T. (1997). Preventing runway incursions. Part 2, ALPA participates in efforts to eliminate the likelihood that human error might lead to an accident on a runway. ***Air Line Pilot, 66*****(7), 10-13.**
Abstract: SUBTITLE: ALPA TO PARTICIPATE IN EFFORTS TO ELIMINATE THE LIKELIHOOD THAT HUMAN ERROR MIGHT LEAD TO AN ACCIDENT ON A RUNWAY

Duke, T. (1999). Runway incursions affect an airline pilot about every other day. ***Air Line Pilot, 68*****(2), 14-17.**

Duke, T. (2000). 12 very serious runway incursions in 1999. ***Air Line Pilot, 69*****(3), 14-15.**

Ebrahimi, Y. S. (1993). ***Parallel runway requirement analysis study. Volume 1: The analysis*** **(Report No. NASA-CR-191549-VOL-1. NAS 1.26:191549-VOL-1).**
Abstract: The correlation of increased flight delays with the level of aviation activity is well recognized. A main contributor to these flight delays has been the capacity of airports. Though new airport and runway construction would significantly increase airport capacity, few programs of this type are currently underway, let alone planned, because of the high cost associated with such endeavors. Therefore, it is necessary to achieve the most efficient and cost effective use of existing fixed airport resources through better planning and control of traffic flows. In fact, during the past few years the FAA has initiated such an airport capacity program designed to provide additional capacity at existing airports. Some of the improvements that that program has generated

thus far have been based on new Air Traffic Control procedures, terminal automation, additional Instrument Landing Systems, improved controller display aids, and improved utilization of multiple runways/Instrument Meteorological Conditions (IMC) approach procedures. A useful element to understanding potential operational capacity enhancements at high demand airports has been the development and use of an analysis tool called The PLAND BLUNDER (PLB) Simulation Model. The objective for building this simulation was to develop a parametric model that could be used for analysis in determining the minimum safety level of parallel runway operations for various parameters representing the airplane, navigation, surveillance, and ATC system performance. This simulation is useful as: a quick and economical evaluation of existing environments that are experiencing IMC delays, an efficient way to study and validate proposed procedure modifications, an aid in evaluating requirements for new airports or new runways in old airports, a simple, parametric investigation of a wide range of issues and approaches, an ability to tradeoff air and ground technology and procedures contributions, and a way of considering probable blunder mechanisms and range of blunder scenarios. This study describes the steps of building the simulation and considers the input parameters, assumptions and limitations, and available outputs. Validation results and sensitivity analysis are addressed as well as outlining some IMC and Visual Meteorological Conditions (VMC) approaches to parallel runways. Also, present and future applicable technologies (e.g., Digital Autoland Systems, Traffic Collision and Avoidance System II, Enhanced Situational Awareness System, Global Positioning Systems for Landing, etc.) are assessed and recommendations made. (Derived from text)

Edwards, V. & Evers, C. (1999). Inductive Loop Technology (LOT) as an alternative surface surveillance system - Demonstration results. In: *Gateway to the new millennium; Proceedings of the 18th Digital Avionics Systems Conference (DASC), Saint Louis, MO, Oct. 24-29, 1999. Vol. 1* (A00-21178 04-01), Piscataway, NJ: Institute of Electrical and Electronic Engineers, Inc.

Abstract: Under the Runway Incursion Reduction Program (RIRP), the FAA is investigating the use of inductive loop technology (LOT) as an alternative non-cooperative surface surveillance sensor. A LOT prototype surveillance system has been installed at Long Beach Airport (LGB) in California. This paper presents some test results and status of this implementation of an existing technology inductive loops, into a new area - the airport surface. The paper will provide an overview of the program, technologies investigated, and test results obtained from the installation at Long Beach airport.

Edwards, V., Daskalakis, A. C., Oswald, L. J., Brading, J., Warren, R., Dawes, N., & Ubnoske, M. (1998). *RUNWAY STATUS LIGHTS EVALUATION REPORT* (Report No. 0900), 360p.

Abstract: The Federal Aviation Administration (FAA) conducted a proof-of-concept demonstration of the Runway Status Lights (RWSL) at Bostons Logan International Airport. The RWSL, employing a network of lights on the airport movement surface, conveys information to enhance the pilots situational awareness of airport operations and to reduce the incidence of runway incursions and airport surface accents. The FAA extended the effort conducted previously by MIT Lincoln Laboratory by installing an operational system in a live environment, integrating the system with primary radar, designing and installing a prototype lighting system and demonstrating the performance requirements needed to uncover the lights. Maximum use of commercial off-the-shelf equipment (COTS) hardware and software was utilized to minimize cost and expedite the challenging schedule. The RWSL proof-of-concept demonstration accomplished all of its

engineering objectives. One hundred hours of data were collected, representing 8298 operations involving arriving and departing aircraft with the network of lights covered, i.e. not observable to the pilots. The analysis of the data was used as a baseline to define system performance. The performance of the lighting network registered over 98% agreement with the Air Traffic Control (ATC) instructions. Because of restrictive limitations placed on uncovering the network of lights to pilots, statistically significant quantitative information was not collected. Specific recommendations and suggestions for improvement are included in this document.

Eggert, J. (1994). Demonstration of runway status lights at Logan Airport. ***The Lincoln Laboratory Journal, 7*****(2), 169-186.**
Abstract: Lincoln Laboratory has developed a prototype runway-status light system (RSLS) designed to prevent runway incursions and accidents. These status lights will tell aircraft pilots and surface-vehicle operators when runways are unsafe to enter or unsafe for departure. This status information will improve the situational awareness of pilots and vehicle operators, thereby reducing the number of runway incursions and accidents. The goal of the RSLS Logan Demonstration is to use automatic processing of surface primary and approach secondary radar data to drive simulated runway-status lights in a real-time but off-line surface-traffic automation system. This article presents a description of the design motivation, methodology, and implementation for the RSLS Logan Demonstration; it also provides an overview of the entire system on a functional block scale and gives introductory descriptions of the various subsystems.

Eggert, J. R., Sasiela, R. J., Kastner, M. P., Harman, W. H., & Wilhelmsen, H. (1995). ***Runway Status Light System Demonstration at Logan Airport*** **(Report No. PB2000-100504/XAB. ATC-206). Washington, DC: Federal Aviation Administration, Department of the Air Force.**
Abstract: The Runway Status Light System (RSLS), developed under the FAA's Airport Surface Traffic Automation (ASTA) program, is intended to help reduce the incidence of runway incursions and airport surface accidents. It will do so by providing a preventive, back-up system of automatically controlled lights on the airport surface that inform pilots when runways are unsafe for entry or takeoff, and by providing controllers with enhanced surface radar displays. This report documents a proof-of-concept evaluation of the RSLS at Boston's Logan Airport. It details the methods used to provide the necessary surface surveillance and safety logic to allow a computer to operate the runway status lights and associated controller displays without human assistance.

European Commission (1996). ***Transport Research - Requirements for a Functional Organization of the Control Tower Operations and Tools.*** **Luxembourg: Office for Official Publications of the European Communities.**
Abstract: This report is concerned with requirements for a functional organization of control tower operations and tools. The ultimate goal being to increase the overall efficiency of aerodrome operations by a system, accepted by the personnel, which reduced a controller's workload. It includes the results of a study carried out to acquire details of the actual control tower organization and environment. With emphasis on the ergonomics factors this information is used to produce fundamental requirements for improved functional work organization based on implementation of new surveillance devices. The new human machine interface (HMI) has to be considered in the reorganized working procedures. The study took place in 3 phases: data were collected on existing working methods, systems, procedures and functional organisation of work at 5 major European airports; the collected data were analysed; general recommendations and

suggestions were elaborated on the use of new systems in the control tower environment and on a reorganization of the work. The scope of this phase is to outline the influence of the new systems and the conditions to achieve capacity benefits. According to these 3 phases, the final report consists of 3 main chapters: analysis of aerodrome control operation; functional requirements and recommendations; conditions for capacity benefits.

Farrell, J., & McConkey, E. (1998). Quantum improvement in airport surface surveillance. In: *Institute of Navigation, National Technical Meeting 'Navigation 2000', Long Beach, CA, Jan. 21-23, 1998, Proceedings* (pp. 749-752.), Alexandria, VA: Institute of Navigation.

Abstract: The Airport Movement Area Safety System (AMASS) is devised to anticipate runway incursions so that they can be prevented. This critically important function is planned to operate with inputs from triangulation and/or Airport Surface Detection Equipment (ASDE). Superior performance will clearly result from superior accuracy at the input, followed by rigorous formation of closest approach time and distance for every possible pairing.

Federal Aviation Administration (1991). Runway incursions: Their causes and current FAA efforts to alleviate them. *FAA Aviation Safety Journal, 1*(2), 4-6.

Federal Aviation Administration (1992). *Reducing runway incursions: Can you relate?*. Washington, D.C.: Federal Aviation Administration.

Federal Aviation Administration (1992). *Reducing runway incursions: An FAA report.* Washington, D.C.: Federal Aviation Administration.

Federal Aviation Administration (1998). *1998 Airport surface operations safety action plan to prevent runway incursions and improve operations*. Washington, D.C.: Federal Aviation Administration.

Federal Aviation Administration (1998). AIRCRAFT SAFETY ON THE RUNWAY. *Volpe Transportation Journal,* 22-28.

Abstract: As airports become more congested, both the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA) are emphasizing improving safety operations while planes are moving on the ground, from touchdown to being airborne again. During these times, pilots' visibility from the cockpit of large aircraft is limited and air traffic controllers' view of the airport is often restricted by buildings or bad weather. In support of the FAA's Runway Incursion Reduction Program, several systems are being evaluated which are designed to prevent on-ground collisions at both the largest airports and those that are less congested.

Federal Aviation Administration (1998). *AIRPORT SURFACE OPERATIONS SAFETY ACTION PLAN, 1998: TO REDUCE RUNWAY INCURSIONS AND IMPROVE OPERATIONS.* 54p.

Abstract: This 1998 Action Plan represents a systemwide, multifaceted strategy to reduce incidents and accidents directly attributable to runway incursions and improve airport surface operations. It identifies goals, objectives, and actions that address management and procedural changes; improvements in airport navigation aids, signs and surface markings; technology-based efforts; and increased incursion awareness efforts. The plan is in direct support of the FAA Administrator's goal to reduce runway

incursions by 15% of the 1997 level by the year 2000.

Fotos, C. (1990). Northwest 727, DC-9 Crash in Detroit Renews Ground Control Safety Issue. *Aviation Week & Space Technology, 133,* 33(0005-2175).

Fotos, C. (1991). NTSB Blames DC-9 Crew Error for Detroit Runway Collision. *Aviation Week & Space Technology, v. 134,* 27-8(0005-2175).
Abstract: The National Transportation Safety Board (NTSB) recently announced its findings concerning the runway collision last December of two Northwest Airlines aircraft at Detroit Metropolitan Airport. The NTSB cited insufficient crew coordination by the pilots of the taxiing McDonnell Douglas DC-9 that wandered onto a fog-covered runway and was struck by the wing of a Boeing 727 that was taking off. The board said that ground control errors, faulty weather observations, and a confusing airport layout also contributed to the accident.

Freer, D. (1989). The maturing of commercial aviation. *Exxon Air World, 41*(1), 45-48.
Abstract: Of all the major operational factors influencing the character of commercial aviation's development over the next 50 years, none will be so profound and pervasive in its influence as that of airport capacity and the difficulty of existing capacity's expansion. This fundamental constraint will necessarily influence commercial aircraft size and design as well as fleet composition, and lead to continued regulatory encroachments on 'freedom of airspace' and a widening of current ATC restrictions. Collision-avoidance systems will be employed globally, in conjunction with satellite navigation systems. Tilt-rotor VTOL aircraft are anticipated to be a major success among the most recent design innovations. (O.C.)

Fuerst, S., Werner, S., Dickmanns, D., & Dickmanns, E. (1997). Landmark navigation and autonomous landing approach with obstacle detection for aircraft. In: *Enhanced and synthetic vision 1997; Proceedings of the Meeting* (28-39). Bellingham, WA: Society of Photo-Optical Instrumentation Engineers.
Abstract: A machine perception system for aircraft and helicopters using multiple sensor data for state estimation is presented. By combining conventional aircraft sensors like gyros, accelerometers, artificial horizon, aerodynamic measuring devices and GPS with vision data taken by conventional CCD-cameras mounted on a pan-and-tilt-platform, the position of the craft can be determined as well as the relative position to runways and natural landmarks. The vision data of natural landmarks are used to improve position estimates during autonomous missions. A built-in landmark management module decides which landmark should be focused on by the vision system, depending on the distance to the landmark and the aspect conditions. More complex landmarks are modeled with different levels of detail that are activated according to range. A supervisor process compares vision data and GPS data to detect mistracking of the vision system due to poor visibility, and tries to reinitialize the vision system or to set focus on another landmark available. During landing approach obstacles like trucks and airplanes can be detected on the runway. The system has been tested in real-time within a hardware-in-the-loop simulation. Simulated aircraft measurements corrupted by noise and other characteristic sensor errors have been fed into the machine perception system. Results from real-time simulation runs are given.

Geisinger, K. E.(1985). Airspace Conflict Equations. *Transportation Science, 19,* 139-53 (0041-1655).

Gempler, K. S. (1999). ***Display of Predictor Reliability on a Cockpit Display of TrafficInformation: Master's thesis.*** **Unpublished doctoral dissertation, Illinois University at Urbana-Champaign. Illinois University.**

Abstract: To improve the availability of information to the pilot concerning other traffic, the concept of a Cockpit Display of Traffic Information (CDTI) has been developed through efforts by NASA. These displays make information about the pilot's own aircraft and others in the flying environment visible, enabling pilots see potential conflicts and avoid them with the most effective maneuvering. These displays support the challenge of free flight, where the pilot becomes more autonomous in deciding exact routing of his aircraft between destinations. With this autonomy from Air Traffic Control, comes an increase in requirements for the pilot to be aware of the position of both his own aircraft and other traffic that may pose a conflict. Therefore, information about ownship and othership's current and future positions must be displayed so the pilot can choose a course, speed, and altitude that will maintain safe separation from other aircraft. To increase the efficiency of maneuvers (saving costs in terms of fuel and delays) the pilot will need to make maneuvering decisions based on predicted aircraft separation well in advance of a possible conflict. The development of this CDTI system has raised several psychological issues, many of which have already been investigated.

Go, G., & Ianniello, J. (1994). Enhanced airport surface surveillance radar. In: ***AIAA/IEEE Digital Avionics Systems Conference, 13th, Phoenix, AZ, Oct. 30-Nov. 3, 1994, Proceedings*** **(p. 544-551), New York: Institute of Electrical and Electronics Engineers, Inc.**

Abstract: The FAA is installing the third generation of Airport Surface Detection Equipment (ASDE-3) in 35 of the busiest U.S. airports. This major advancement over existing equipment uses modern radar and display technology to provide ground controllers with a crisp, clutter-free display of surface targets, even under conditions of severely limited airport visibility. Modern graphics technology provide flexible traffic situation displays that include airport map overlays on radar data and expanded area windowing capabilities. Recent R&D enhancements extend the function of ASDE-3 to further aid ground controllers and enhance airport safety. Information from sensors monitoring approaching aircraft, and nonradar sensors reporting aircraft position have been fused to automate potential runway incursion warnings and add aircraft identification tags on traffic situation displays. Significant cost reductions resulting from R&D activities can make it economically feasible to deploy lower cost systems in more airports. This paper describes the design and implementation of ASDE-3, and the improvements that can reduce the burden on controllers, increase airport efficiency, and enhance air travel safety.

Go, G., & Iannnielo, J. (1994). Third generation airport surface detection equipment design. In*: NAECON 94; Proceedings of the IEEE 1994 National Aerospace and Electronics Conference, Dayton, OH, May 23-27, 1994. Vol. 2* **(p. 1301-1308). New York: Institute of Electrical and Electronics Engineers, Inc.**

Abstract: The FAA under the National Airspace System Plan is modernizing its airport radar for surface surveillance. Part of this modernization program includes the installation of the third-generation of Airport Surface Detection Equipment known as ASDE-3. This major advancement over existing equipment uses modern radar technology to provide ground controllers with a crisp, clutter free display of surface targets, even under conditions of severely limited airport visibility. Modern digital technology provides advanced viewing capabilities. These include airport map overlays and operator-selectable window insets on each display. The windows can be rotated and magnified.

These features allow critical areas to be viewed clearly, providing valuable assistance to ground traffic controllers. The high quality of the processed radar returns is being used to extend the function of ASDE-3 to further aid the ground controllers and enhance airport safety. Information from sensors monitoring approaching aircraft has been combined with ASDE-3 to provide automatic runway incursion warnings. This paper describes the design and implementation of ASDE-3. Methods are proposed to expand ASDE-3 to support the next generation of automatic traffic monitoring systems.

Graham, B. (1996). ***Tools Evaluation Control Centre, Copenhagen*** **(Report No. PB97-101075. EEC-295). Brussels, Belgium: European Organization for the Safety of Air Navigation, Directorate of Civil Aviation, Copenhagen.**
Abstract: This report describes a live evaluation of an ODID IV Controller Working Position (CWP) in the Copenhagen Air Traffic Control Centre. The CWP was operated in 'shadow' mode which permitted a comparison between the current Copenhagen system (radar display, touch input device and paper strips) and ODID (an advanced working interface where paper strips have been replaced by graphical and tabular displays of flight plan and conflict information). The impact of graphical tools displaying predicted traffic situations as observed during this evaluation would be the ability of the planning controller to reduce radar controller workload through pre-planning the traffic situation and advanced resolution of predicted conflicts. The evaluation has highlighted the importance of accurate trajectory calculation, trajectory recalculation, and conformance monitoring.

Hanson, E. R., Jr. (1998). Avoiding Runway Incursions. ***Business and Commercial Aviation, 82*****, 76-8+(0191-4642).**
Abstract: The writer outlines some operational strategies for avoiding runway incursions. The most obvious of these is to get a clearance to cross every runway that you approach. Other recommended strategies are to turn on landing lights on approach to the runway, to review the airport layout each time you ready an aircraft for movement, and to have both pilots listen to and write down the clearance when it is received in the cockpit.

Harrison, M. J. (1991). Runway incursions and airport surface traffic automation. ***SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Sept. 23-26, 1991. 12 p.***
Abstract: Runway incursions occur when aircraft or vehicles get onto a runway and conflict with aircraft cleared to land or take off on that same runway. All are caused by human error. The Federal Aviation Administration has identified reducing these human errors as a safety priority. Application of new technology is part of the solution. This paper highlights recent actions by the agency in addressing runway incursions and discusses a strategy for development of airport surface traffic automation designed to aid the air traffic controller and the pilot in identifying potential runway incursions. Airport surface traffic automation represents a conflict alert system which adds both automated safety monitoring and tools for the controller to use in reducing surface movement delays.

Hendricks, W. R. (1988). Data Bases of Aviation Incidents Resulting from Human Error. In ***Human Error Avoidance Techniques Conference Proceedings*** **(pp. 27-36) (Publication No. P-204). Warrendale, PA: Society of Automotive Engineers.**
Abstract: This paper presents a description of several Federal Aviation Administration (FAA) incident data systems that contain information on events which result primarily

from human error. These data systems include reports of near midair collisions, operational errors, pilot deviations, and events reported through the Aviation Safety Reporting System (ASRS). Over 17,000 incident reports are received and stored in these data bases annually. This paper discusses the information content of the data bases, reporting procedures, system limitations, proposed improvements, and uses of the data.

Herdricks, B. (1980/1988). ***Runway incursions: The trouble ahead.*** **Helliwell, Inc.**

Hicok, D. S., & Lee, D. (1998). Application of ADS-B for airport surface surveillance. In: ***DASC - AIAA/IEEE/SAE Digital Avionics Systems Conference, 17th, Bellevue, WA, Oct. 31-Nov. 7, 1998, Proceedings. Vol. 2*** **(p. F34-1 to F34-8), Piscataway, NJ: Institute of Electrical and Electronics Engineers, Inc.**
Abstract: Automatic Dependent Surveillance Broadcast (ADS-B) is a function on an aircraft or ground vehicle that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. The broadcast ADS-B message provides surveillance information to other users, principally ATC and aircraft/vehicle operators. The applications for ADS-B include ATC display of traffic, runway incursion detection and alerting, and Cockpit Display of Traffic Information (CDTI). The FAA and NASA are investigating the suitability of this technology to support these applications in the airport surface environment. NASA has recently tested ADS-B using 1090-MHz data transmission in an airport surface environment as part of the Low Visibility Landing and Surface Operations (LVLASO) program. This paper presents results of the ADS-B testing and an assessment of how well 1090 MHz ADS-B performs with respect to surveillance system requirements established by ICAO and RTCA. In addition, data collected from vehicle-to-vehicle tests is analyzed to determine how well on-board avionics can utilize ADS-B data.

Hilkevitch, J. (1998). Near Collision Prompts FAA to Retrain Controllers Critics Say Action Ignores Staffing, More Flights. ***Chicago Tribune,*** **(1085-6706).**
Abstract: While refusing to draw a connection between a steady growth in commercial air travel and a double-digit increase in mistakes by the nation's air-traffic controllers over the last year, the Federal Aviation Administration said Friday it has ordered refresher courses for 10,000 controllers whose main responsibility is separating aircraft on runways. The unusual action affects nearly two-thirds of federal air-traffic controllers, a move that the controllers union and some aviation experts said amounts to an overreaction to one incident--a near collision involving two passenger jets this spring at La Guardia Airport in New York City. An FAA memo obtained by the Tribune indicates that the near collision just 200 feet above the ground between an Air Canada Airbus A320 and a US Airways DC-9 influenced the retraining decision made by James Washington, the FAA's acting director of air traffic. In that April 3 incident, what the FAA and the controllers union agreed was a judgment error by a veteran controller in the La Guardia tower resulted in the departing Airbus and the arriving DC-9 passing within 40 feet of each other.

Hitchcock, L., Paul, L. E., Shocket, E., & Algeo, R. D. (1989). ***Dallas/Fort Worth simulation. Volume 2: Appendixes D, E, and F*** **(Report No. AD-A216613. DOT/FAA/CT-TN89/28-VOL-2). Atlantic City, NJ: Federal Aviation Administration.**
Abstract: A series of dynamic, real time, air traffic control simulations of selected aspects of the D/FW Metroplex Air Traffic System Plan were conducted. Using D/FW controllers as subjects, the simulations provided an opportunity to evaluate proposed changes in area flow patterns and traffic management and to experience simultaneous

approaches to the four parallel runway configuration under consideration for D/FW. The results of these simulations demonstrated that, even when faced with up to twice their normal traffic load, the controllers could maintain a smooth and safe flow of traffic using the new configurations proposed for the D/FW area. The D/FW Evaluation Team declared that the parallel arrival routes, separate altitudes for high performance turboprops, increased departure routes, and stratified sectors all proved to be valuable controller tools. In addition, simulation of the four simultaneous parallel approaches led to the Evaluation Team to enthusiastically endorse the concept of four simultaneous approaches to the D/FW airport and to affirm that in each and every case the concept proved to be safe even though frequently challenged by the unlikely conditions of 30 degree blunders without communications.

Hockaday, S. & Chatziioanou, A. (1986). An Analytical Method for Aircraft Collision Risk Estimation. *Transportation Research. Part B, Methodological, 20B,* 415-28(0191-2615).

Hollister, W. M. (1988). *Airport surface traffic automation study* (Report No. AD-A194553. ATC-156. DOT/FAA/PS-87/1). Lexington: Massachusetts Institute of Technology. Abstract: This report documents a study of requirements for an Airport Surface Traffic Automation (ASTA) system. The objective was to determine the necessary functions, establish the cost and benefits, and outline a modular system design. The highest priority function identified was an improved surface surveillance and communication system. The greatest potential for safety benefits is provided by automatic conflict alert and collision warning for pilots and controllers to prevent runway incursion accidents. Strategic and tactical planning assistance to maximize runway utilization can improve controller productivity while keeping them responsible for final decisions. The report contains a modular design for ASTA and includes specifications for a man-in-the loop simulation of the system.

House Committee on Government Operations. Government Activities and Transportation Subcommittee (1991). *Tragedy at LAX: Runway incursions and the federal response:* Hearing before the Government Activities and Transportation Subcommittee of the Committee on Government Operations, House of Representatives, One Hundred Second Congress, first session, February 25, 1991. Washington, D.C.: U.S. Government Printing Office.

House Committee on Public Works and Transportation. Subcommittee on Aviation (1991). *Ground collisions and runway incursions:* Hearing before the Subcommittee on Aviation of the Committee on Public Works and Transportation, House of Representatives, One Hundred Second Congress, first session, February 28, 1991. Washington, D.C.: U.S. Government Printing Office.

House Committee on Public Works and Transportation. Subcommittee on Investigations and Oversight (1988). *Aviation safety near midair collisions and runway incursions* (100-14): Hearing before the Subcommittee on Investigations and Oversight of the Committee on Public Works and Transportation, House of Representatives, One Hundredth Congress, first session, April 9, 1987. Washington, DC: U.S. Government Printing Office.

Idris, H. R., & Simpson, R. W. (1998). New approach to the planning and control of air traffic in the terminal area. In: *AIAA Guidance, Navigation, and Control Conference*

and Exhibit, Boston, MA, Aug. 10-12, 1998, Collection of Technical Papers. Pt. 2 **(p. 957-970), Reston, VA: American Institute of Aeronautics and Astronautics.**
Abstract: A new approach to the planning and control of the traffic in the terminal area is proposed which combines the path generation and conflict avoidance problems into one problem. The objective is to generate conflict-free paths for all aircraft in the terminal area in order to meet the given landing schedule at the runway. It is assumed that the given schedule guarantees the existence of such conflict-free paths; otherwise, the schedule needs to be revised accordingly. This paper presents the concept geometrically, and results in an algorithm which generates conflict-free paths for all aircraft simultaneously.

IEEE/AIAA (1992). ***IEEE/AIAA Digital Avionics Systems Conference, 11th, Seattle, WA, Oct. 5-8, 1992, Proceedings.*** **New York: Institute of Electrical and Electronics Engineers, Inc.**
Abstract: (For individual items see A94-19152 to A94-19249)The papers presented in this volume provide an overview of recent developments in the field of digital avionics, with particular reference to civil, military, and space applications. General topics discussed include vehicle management systems; communication, navigation, and identification; synthetic vision; systems engineering methods and tools; rotorcraft avionics; and airport safety systems. Other topics covered include fault tolerant avionics, artificial intelligence and expert systems, modular avionics technology, sensors and signal processing, crew station technology, software engineering, optical technologies and systems, and crew station human factors. (AIAA)

Illuminating Engineering Society of North America, Aviation Lighting Committee, Recommended Practice Subcommittee (1987). ***IES Recommended Practice for Airport Service Area Lighting*** **(Publication No. IES-RP-14-1987). New York: Illuminating Engineering Society.**
Abstract: Considerable effort has been expended by professional and governmental authorities in analyzing and solving the problems relating to airport approach, runway and taxiway lighting. Yet relatively little has been done to solve another problem that has a direct bearing on the success or failure of the airport's operational lighting system. This is the question of airport service area lighting. According to major airline and airport operators, most believe the lack of proper ramp or loading/unloading apron lighting at many existing airports is costing them money and is dangerous to flight crews, maintenance and ground service personnel, and passengers. Further the Committee believes initial service area lighting installations made on new or improved airport terminal facilities should be accomplished according to nationally recognized standards for good lighting practice as adapted to this particular task. It is the purpose of this Practice not only to define the task and somewhat severe limitations usually imposed upon pertinent lighting methods, but also to suggest methods of solving the lighting problems in such ways that service area lighting will augment operational lighting installations, rather than detract from their overall effectiveness.

Jackson, A., & Pichancourt, I. (1995). ***Human-Machine Interface Reference System for EnRoute Air Traffic Control*** **(Report No. PB96-152285. EEC-292). Bretigny-sur-Orge, France: EUROCONTROL Experimental Centre.**
Abstract: The report provides a description of a 'state-of-the-art' graphical interface for en route air traffic control, based on a Planning Controller (PC), Tactical Controller (TC) partition. It describes the graphical interfaces necessary to support both the PC and the TC functions but makes minimal assumptions concerning the nature of the hardware

employed to realize the Controller Working Position (CWP), i.e. it assumes the availability of high resolution interactive graphics without specifying the nature of the physical screens or software employed to realize the implementation. The specification is intended to provide a Reference Ground Human Machine Interface (REFGHMI) which can be used as both a measurement baseline and as a starting point for the development of interfaces exploring and exploiting the more advanced functionality made possible by technical developments such as ground-air datalinks, improved trajectory prediction, multi-sector planning, etc.

Jain, A. (1994). Applications of millimeter-wave radars to airport surface surveillance. In: *AIAA/IEEE Digital Avionics Systems Conference, 13th, Phoenix, AZ, Oct. 30-Nov. 3, 1994, Proceedings* (p. 528-533), New York: Institute of Electrical and Electronics Engineers, Inc.

Abstract: Developments in MMIC technology and ceramic electronic scan antennas have made low power, low-cost, mm-wave radars practical. Two such radar systems scheduled for high-volume commercial production are the W-Band Adaptive Cruise Control Radar for automobile collision avoidance and the Ka-Band Landing Aids Radar for the airborne enhanced vision system. Data collected at the Los Angeles International Airport for aircraft and surface traffic, in various modes of operation, is presented. The data show that these radar systems can reliably measure the position and velocity of an aircraft or a surface vehicle in the different situations encountered on the airport surface. A system utilizing a collection of these radar units can provide reliable runway incursion warnings. These radar units, in combination with an interrogation and identification system, can be used to provide the needed data inputs to an airport traffic planner, or alternatively to enhance the performance of a primary airport surface surveillance system.

Jentsch, F. (1994). The Effects of Taxiway Light Geometry, Color, and Location on Position Determination by Pilots. In *People and Technology in Harmony: Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, Volume 1* (pp. 76-80). Santa Monica, California: The Human Factors and Ergonomics Society.

Abstract: Lack of perspective cues or abundance of lights in airport taxiway areas have been problems leading to pilot disorientation when navigating on the airport surface. Possible human factors solutions include the introduction of perspective cues through shaped lights and the reduction of extraneous light signals with shielded lights. Thirty-two pilots participated in a laboratory simulation to evaluate the effects of taxiway light geometry, colour, and location on determination of position. Two new systems (shielded and shaped lights) were tested against two traditional systems (blue edge lights and green centreline lights). Subjects had to determine their position on an airport map from static, out-the-cockpit views. Contrary to expectations, the two new systems did not lead to improved performance over the traditional systems in this simulation. In fact, the pattern of means suggested that performance was better with the traditional systems than with the new ones. In the case of the number of correctly identified positions, these differences were significant. Subjects' confidence and their actual performance in position determination did not correlate. Implications for studies investigating airport surface navigation systems are discussed.

Johnson, K. (1996). Pilot Provides Clues to Ill. Runway Crash. *USA Today* (0734-7456).

Abstract: Investigators looking onto a deadly runway collision in Qunicy IL between a United Express commuter plane and a private plane Nov 19, 1996 got details Nov 21 from a local pilot who was on the same airfield awaiting takeoff about the same time the crash occurred. Fourteen people were killed in the crash.

Jones, D. R., & Young, S. D. (1994). ***Enhancing pilot situational awareness of the airport surface movement area.*** **Presented at Digital Avionics Systems Conference, Phoenix, AZ, (p. 10P).**

Abstract: Two studies are being conducted to address airport surface movement area safety and capacity issues by providing enhanced situational awareness information to pilots. One study focuses on obtaining pilot opinion of the Runway Status Light System (RSLS). This system has been designed to reduce the likelihood of runway incursions by informing pilots when a runway is occupied. The second study is a flight demonstration of an rate integrated system consisting of an electronic moving map in the cockpit and display of the aircraft identification to the controller. Taxi route and hold warning information will be sent to the aircraft data link for display on the electronic moving map. This paper describes the plans for the two studies.

Jones, M. B., & Kennedy, R. S. (1996). Isoperformance Curves in Applied Psychology. ***Human Factors, 38*****(1), 167-182.**

Abstract: Isoperformance is a technique for reading information out of a data-analytic model, comparable to expected mean square or omega squared analyses. It results in a trade-off function (an isoperformance curve) among the determinants of performance. The technique was developed primarily to generate trade-off functions between personnel aptitude and time in training or on the job. However, the technique is general and can be applied in any trade-off situation. In part, the purpose of this paper is to recall the antecedents of isoperformance in psychophysics and to recount the origins and development of the isoperformance readout. Its main purpose, however, is to present several examples of isoperformance curves in applied psychology and to make the case for their usefulness.

Katz, E. (1996). ***Evaluation of L-8O4 Elevated Runway Guard Light Fixtures*** **(Report No. AD-A307589. DOT/FAA/AR-TN96/18. NIPS-96-72303). Atlantic City, NJ: Federal Aviation Administration.**

Abstract: The number of inadvertent runway incursions has grown during recent years, increasing the importance of protective visual guidance systems for incursion prevention. One such visual system is the L-804 elevated runway guard light fixture. Also known as a wig-wag light, these fixtures contain two alternately flashing yellow lights and are used to help identify runway holding positions to pilots. Pilots, however, have indicated that the light intensity (600 candelas minimum average intensity) and flash rate (average of 35 flashes per minute per lamp) of the L-804s are inadequate. The L-804s were examined under day and night Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) conditions from various distances and angles. Particular attention was paid to performance characteristics such as intensity, flash rate, vertical and horizontal aiming angle, lamp separation, and the usefulness of providing a hood over each lamp. As a result of the evaluation it was determined that the L-804 specifications needed to be modified. Flash rate should be increased to 45 to 50 flashes per minute per lamp. The light intensity of the Mode 1 (constant current) L-804 when energized at 6.6 amps and tested with one lamp in the steady burning mode and the other lamp masked out should be 4100 candelas. The light intensity of the Mode 2 (constant voltage) L-804 when energized at 120 volts and similarly tested should be 940 candelas.

Katz, E. S. (2000). ***Evaluation of a Prototype Advanced Taxiway Guidance System (ATGS)*** **(Report No. PB2000-103678/XAB. DOT/FAA/AR-TN00/9). Atlantic City, NJ: William J. Hughes Technical Center.**

Abstract: The Federal Aviation Administration (FAA) Office of Aviation Research, Airport Technology Research and Development Branch, AAR-410 has designed, installed, and evaluated a prototype Advanced Taxiway Guidance System (ATGS) at the Atlantic City International Airport (ACY). The principal feature of this prototype is automatically controllable taxiway lighting, which is used to provide improved surface route guidance to taxiing aircraft. The system automatically illuminates a specific taxiway route for each arrival and departure thus reducing the chances of an aircraft making a wrong turn. The system is also designed to detect and provide Air Traffic Control (ATC) alarms for potential runway incursions, pilot route deviations, and route conflicts between aircraft.

Katz, E. S., & Stein, E. S. (1992). ***Prototype stop bar system evaluation at John F. Kennedy International Airport*** **(Report No. AD-A258667. DOT/FAA/CT-92/24). Atlantic City, NJ: Federal Aviation Administration.**

Abstract: A prototype stop bar system was installed and evaluated at John F. Kennedy International Airport. The purpose of the year-long evaluation was to gain operational experience on the use of a stop bar system and how it could possibly impact the air traffic system. To determine the effectiveness of the stop bar system, data were collected from both user pilots and air traffic controllers. Results of the pilot data indicate that the system is somewhat effective in preventing inadvertent runway incursions, but not as effective as stop bar systems operating at European airports. Results of the air traffic controller data indicate that although the majority of the controllers felt that stop bars are conceptually a good idea, almost all of them agreed that the system was not acceptable, especially when combined with the local control position at moderate to high traffic load.

Kelley, D. R., & Adam, G. L. (1997). The Human Factors of Runway Incursions Caused by 'Pilot Error': A Survey of U.S. Airline Pilots. In R. S. Jensen and L. A. Rakovan (Eds.) ***Proceedings of the Ninth International Symposium on Aviation Psychology, Volume 2*** **(911-917).**

Abstract: A study was conducted of ways to reduce runway incursions by identifying factors relevant to the causes and prevention of what is often classified as 'pilot error'. The study approach included developing a comprehensive questionnaire on topics identified from an earlier review of reports of pilot deviations during surface operations. These reports indicated that most errors occurred when the pilots were doing what they usually do; thus the survey addressed usual day-to-day surface operations and gathered information from pilots even if they had not been involved in an actual incursion or related surface incident. The information was analyzed to identify specific potential factors causing or preventing pilot errors. Findings are reported regarding the need to increase pilot familiarity with airports, improve airport surface navigation aids, enhance ATC-pilot communications, develop cockpit procedures and intracockpit communications for airport surface operations, standardize the use of exterior aircraft lights to increase aircraft conspicuity, improve ATC procedures relevant to taxiing aircraft into position and hold on the runway, revise the federal aviation regulation on crossing runways during taxi, respond to pilot concerns about land-and-hold-short operations, and counter pilot fatigue and poor eating habits during duty times.

Kennedy, R. S. (1989). Correction. ***Aviation Space and Environmental Medicine, 60*****(5), 473**

Kennedy, R. S., & Dunlap, W. P. (1990). Assessment of the Vistech Contrast Sensitivity Test for Repeated-Measures Applications. ***Optometry and Vision Science, 67*****(4), 248-251.**

Kennedy, R. S., Wilkes, R. L., Lane, N. E., & Homick, J. L. (1985). Development of a Portable Computerized Performance-Test System. ***Aviation Space and Environmental Medicine, 56*****(5), 502.**

Koerner, W. (1988). LIRAS - A proposal for an airport traffic safety system: <ORIGINAL> LIRAS - Ein Vorschlag fuer ein Flugplatz-Verkehrs-Sicherungs-System. ***Ortung und Navigation, 29*****(3), 331-342.**
Abstract: The design concept and operation of LIRAS, a linear radar system for monitoring aircraft and service-vehicle traffic on airport runways, are discussed and illustrated with extensive drawings, diagrams, and photographs. Consideration is given to the AVES-type (60-GHz CW) surveillance radar sensors and their placement, the 80-GHz FM/CW vehicle-separation radars, takeoff-runway security procedures, the ground-traffic control center and its computer systems, and vehicle identification methods. (T.K.)

Kruk, R., & Regan, D. (1996). Collision avoidance: a helicopter simulator study. ***Aviation, Space, & Environmental Medicine,*** **111-114,**
Abstract: (Compared the accuracy of time-to-contact judgments in 3 field-of-view (FOV) conditions for different combinations of ownship and target velocities. Six pilots flew a helicopter flight simulator with a helmet-mounted display. With a stationary target and ownship forward speed of 60 kt, Ss estimated that collision with a stationary target would occur roughly 200 ms before the actual time to collision in the large and intermediate FOV conditions. When the ownship was stationary and the target was approaching at 60 kts, estimates of collision time showed considerably less lead in the large and intermediate FOV conditions. When the smallest FOV was used, estimates were the same whether closing speed was produced entirely by ownship motion or entirely by target motion. Too-early errors in estimating time to collision may be caused by the impression of self-motion produced by stimulating the peripheral retina with a radially-expanding flow pattern. ((c) 1999 APA/PsycINFO, all rights reserved)

Lau, S. (1998). STOP, LOOK AND LISTEN. ***PROFESSIONAL PILOT, 32*****(10), 122-126.**
Abstract: SUBTITLE: A TEAM APPROACH TO AVOIDING RUNWAY INCURSIONS.

Leckman, P. (1991). Enhanced vision system option on future aircraft. ***SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Sept. 23-26, 1991. (p. 10).***
Abstract: An 'enhanced vision system' (EVS) concept has been developed in connection with studies of future autonomous aircraft whose dependence on ground-based navigational aids is reduced or entirely eliminated. An EVS displays sensor-derived information to a pilot via HUD, facilitating such tasks as the visualization of runway environments during IFR operations. System components are integrated in such a way as to anticipate the control tasks that must be accomplished, in the framework of all relevant human factors. It is anticipated that pilot avoidance of runway incursions in night/low-visibility conditions could be substantially improved. The EVS concept is projected to a future High Speed Civil Transport's 'synthetic vision system'. (O.C.)

Leib, J. (1995). Confusion Reigns in Near-Collision at Snowy DIA. ***Denver Post.***
Abstract: A transcript of conversations between a Denver International Airport tower controller and DIA operations managers shows that confusion followed the entry of an airport vehicle onto an active runway less than two minutes before a United 727 was to land on Oct 23, 1995.

Leiser, K. (1999). Lambert Ranks High in Danger of Collisions on the Ground Last Year, Airport Tied for No. 2 Nationally in "Runway Incursions". *St. Louis Post - Dispatch*.
Abstract: Note: The THREE STAR edition referred to "Trans World Express" as "Trans States." It also identified Jane Garvey as "FAA Director" in the last paragraph. The pilot of a Southwest Airlines flight had to abort his takeoff at Lambert Field Tuesday night after a twin-engine commuter aircraft crossed onto the runway 3,000 feet ahead of him, the Federal Aviation Administration said. The incident marked the latest so-called "runway incursion" at Lambert which ranked near the top for such incidents in a recent nationwide study. Lambert and Newark International Airport in New Jersey were tied for second in the report, issued by the U.S. Department of Transportation.

Leiser, K. (2000). Lambert Still Ranks Poorly in Runway Incidents FAA Figures List 7 "Incursions" Last Year, 8 in 1998; Airport Seeks Ways to Improve. *St. Louis Post - Dispatch*.
Abstract: Lambert Field tied for No. 4 nationally in potentially hazardous runway "incursions" in 1999 with seven, according to preliminary data released Tuesday by the Federal Aviation Administration. If the numbers hold up, last year's total would be three fewer than the nation's worst airport -- Los Angeles International, said FAA spokesman Tony Molinaro. John Mayrhofer, director of runway safety for the FAA, cautioned that final numbers won't be available for another month. It can take 90 days to investigate and verify the encroachments.

Levin, A. (1998). Pilots Protest Procedure After Air Scares. *USA Today*, (0734-7456).
Abstract: Two fast-moving jets came within 30-50 feet of colliding last month at the Charlotte, N.C., airport in an incident some pilots say illustrates the dangers of a controversial landing procedure. A US Airways MD-80 touched down at 9:40 a.m. Nov. 22 and rolled into the path of a US Airways Fokker F-100 taking off on an intersecting runway. The F-100 pilot was forced to "aggressively" lift off early to avoid a collision, according to a Federal Aviation Administration account. The pilots estimated in reports to the FAA that the F-100 passed over the MD-80 at a distance of no more than 50 feet, an unusually close encounter of two passenger jets. The MD-80, which can carry about 140 passengers, had 77 aboard, a US Airways spokesman said. He said he couldn't immediately determine the number aboard the 100-seat F-100.

Levin, A. (1998). Too Close for Comfort? Safety, On-Time Travel on Collision Course, Pilots Say. *USA Today*, (0734-7456).
Abstract: In a practice common in airports across the nation, the United pilot had been cleared to land after promising to stop before reaching the 747's runway. But on this day in May 1997, strong winds made touchdowns less predictable. The United jet could not stop in time. Federal regulators, the airlines and some safety experts say the procedure has never caused an accident and does not increase risk to passengers. The Federal Aviation Administration (FAA) is so confident that it wants to expand use of intersecting runways to landings at night and in the rain. The nation's largest pilots union, however, cites a series of incidents like the one in Chicago. It says its pilots will refuse to use the procedure under any circumstance unless the FAA addresses safety concerns in the next few months. If the pilots make good on their threat, delays could result at almost all airports.

Levin, A. (2000). FAA Aims to Reduce Runway Close Calls. *USA Today*, (0734-7456).
Abstract: WASHINGTON -- Hoping to minimize one of aviation's most serious safety problems, federal authorities will grant partial immunity to pilots whose errors led to

close calls on the runway if the pilots say how the incidents happened. In a program announced Tuesday, the Federal Aviation Administration will not seek penalties or license suspensions against pilots after a runway incident "if an airman cooperates in answering questions." The program will run for one year. So-called runway incursions occur when an aircraft comes too close to another aircraft or a vehicle on a runway. Incursions have surged since the early 1990s, despite repeated attempts to reduce their number.

Lounsbury, L. (1998). SWEEPING THE DIRT UNDER THE RUG? *PROFESSIONAL PILOT, 12*.
Abstract: SUBTITLE: FAA'S NEW ACTION PLAN MINIMIZES RUNWAY INCURSIONS BY MERELY REDEFINING THE PROBLEM.

Lounsbury, L. (1998). UNTANGLING RUNWAY INCURSIONS. *PROFESSIONAL PILOT, 5.*
Abstract: SUBTITLE: MANY FACTORS CONTRIBUTE TO THIS INCREASING PROBLEM.

Lounsbury, L. (1999). Why a little more traffic makes a lot more runway incursions. *Air Line Pilot, 68*(5),10-13

Lyon, E. (1992). The application of automatic surface lights to improve airport safety. In: *IEEE/AIAA Digital Avionics Systems Conference, 11th, Seattle, WA, Oct. 5-8, 1992, Proceedings* (p. 91-96), New York, Institute of Electrical and Electronics Engineers, Inc., 1992.
Abstract: Current efforts aimed at developing automation systems capable of preventing runway incursions are described, with particular reference to FAA's Airport Surface Traffic Automation (ASTA) program. It is noted that a comprehensive surface safety system including ASTA-1 runway status lights and basic alerting functions could have prevented almost 90 percent of the accidents and hazardous incidents described in the incident database. With the inclusion of additional safety products, such direct cockpits alerts and autonomous navigation systems in the cockpit, almost every scenario represented in the incident database is preventable.

Lyon, E. (1993). The application of automatic surface lights to improve airport safety. *IEEE Aerospace and Electronic Systems Magazine.*
Abstract: The first phase of the Airport Surface Traffic Automation (ASTA) program, ASTA-1, which focuses on advanced surveillance, communications, and automation techniques in order to improve airport safety, reduce delays, and increase efficiency, calls for the development of a system of automatic runway status lights located at entrances to runways and in front of positions from which takeoffs commonly begin. Both types of ASTA-1 lights are designed for fully automatic operation in all weather conditions. The system is to operate on the basis of live airport traffic and will validate the operational concept using a scale model of Boston's Logan International Airport plus surveillance displays.

Manningham, D. (1991). Cursed Is the Ground; Danger to Flight Operations Doesn't End on the Ground. *Business and Commercial Aviation, 68,* 72-4.

Marks, A. (1997). Jammed Us Runways Increase Close Calls Growing Number of Near Misses on the Tarmac Redoubles an Effort to Improve Airport Conditions.

***Christian Science Monitor*.**

Abstract: That near miss, known in aviation jargon as a "runway incursion," was caused by simple pilot confusion. The commuter plane's crew missed a turn and strayed onto the wrong runway. During the past four years, reports of runway incursions jumped more than 50 percent, according to the Federal Aviation Administration. That has triggered ire over perceived FAA foot-dragging on a problem that's been around since the late 1970s. It's also engendered frustration at the National Transportation Safety Board (NTSB), which has included runway incursions on its "most wanted" list of airport fixes since 1990. But the problem has also prompted what one FAA official calls the "most cooperative effort I've ever seen" between the FAA, the NTSB, the airline industry, and pilots associations to deal with the problem.

Martin, L. L. (1999). Long Beach Airport Reduces Runway Incursions. *Business & Commercial Aviation, 84*(4), 43.

Abstract: A program that has seen a reduction in the number of runway incursions at Long Beach Airport, California, is reported. The program was initiated by the Federal Aviation Administration and the airport in order to deal with the regular incursion problems being experienced by the airport. Markings were made clearer at the airport and several initiatives were used to increase pilot awareness of the potential problems. As a result of the program, runway incursions have been reduced by 35 percent in 1998 compared to 1997.

Martindale, M. (1990). 11 Airports Outrank Metro for Straying Plane Incidents. *The Detroit News and Detroit Free Press*.

Abstract: Runway incursions occur more frequently at 11 other major US airports than at Detroit Metropolitan Airport, where eight people were killed after two Northwest jetliners collided in fog on Dec 3, 1990.

Mathews, A. W. (2000). Encounters on Runways Held Steady in '99. *Wall Street Journal* (0099-9660).

Abstract: The FAA has made "runway incursions" a top safety priority this year because of the increase. There has also been a spotlight on the issue because of several recent high-profile incidents in which planes came dangerously close to one another. Overall, the number of runway incursions, which can include anything from a near collision between jetliners to a minor incident in which a truck inadvertently strays too close to a moving plane, was up to 327 last year from 325 in 1998. The ratio of runway incursions to airport operations -- takeoffs or landings -- dropped slightly to 0.47 per 100,000 operations in 1999 from 0.49 the year before. But the longer-term trend is up sharply, from 204 and a rate of 0.33 per 100,000 in 1994.

Mayrhofer, J. (2000). 'There Is No Easy Solution'. *USA Today*, (0734-7456).

Abstract: EDITORIALS; Today's debate: Air safety; OPPOSING VIEW: But increasing awareness of problem is key.; John Mayrhofer heads the Federal Aviation Administration's Runway Safety Program. Last year, there were more than 68 million safe takeoffs and landings at almost 500 U.S. airports. This achievement resulted from the exceptional skill and professionalism of tens of thousands of people -- pilots, air traffic controllers and airport vehicle drivers -- responsible for airport safety. Despite that extraordinary effort, the potential for accidents makes reducing the runway incursions that may lead to accidents a top safety priority for the Federal Aviation Administration. Yet the number of individuals involved means there is no easy or single solution.

McCann, R. S., Andre, A. D., Begault, D., Foyle, D. C., & Wenzel, D. C. (1997). Enhancing Taxi Performance under Low Visibility: Are Moving Maps Enough? In *Ancient Wisdom - Future Technology. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, Volume 1.* Santa Monica, California: The Human Factors and Ergonomics Society.

Abstract: The authors report the results of an experiment evaluating the separate and combined effects of a 3-D perspective moving map and newly developed head-up display symbology on taxi performance in low visibility. Nine commercial airline pilots completed a series of gate-to-runway taxi routes at a simulated Chicago-O'Hare. Relative to a baseline condition, in which in-the-cockpit navigation support was confirmed to Jeppesen paper map, the 3-D moving map yielded a nonsignificant increase in taxi speed. The combination of electronic moving map and head-up display yielded a considerably larger and statistically significant increase in taxi speed. These results suggest that in low visibility, head-up displays can substantially improve taxi performance, over and above any improvements associated with 3-D moving maps.

McDonald, N. & Fuller, R. (1994). The Management of Safety on the Airport Ramp. In N. Johnston, N. McDonald, & R. Fuller (Eds.) *Aviation Psychology in Practice* (pp. 68-86). Aldershot, Hampshire: Avebury Technical, Ashgate Publishing.

McGinley, L. (1990). Risk of Airliner Collisions on Runways Is Growing Concern for Safety Experts. *Wall Street Journal,* (0099-9660).

Abstract: Airline safety experts are getting increasingly jittery about the possibility of airliner collisions on the ground. The worries are being fueled by increases in "runway incursions," the term for planes and trucks being on the runways when they aren't supposed to be.

McKelvey, R. K. (1987). Colour Dependence and Surplus Information in Airport Visual Aids during VFR Operations. *Journal of Navigation, 40*(2), 206-226.

Abstract: Airport visual aids are examined for failure of transfer from chromatic (i.e. normal) to achromatic viewing situations which would suggest a non-redundant use of colour, and for their information value during VFR (visual flight rule) operations as a function of the airport operating classification for which they were designed. From photographs taken under visual meteorological conditions at night, slide sequences representing the visual presentations associated with aircraft movements during taxi-out, take-off, approach and landing operations were prepared and shown to experienced pilots in a time-stressed forced-choice procedure. The results suggest that among displays in current use only the signal light from the control tower is completely colour-dependent. Also, the information value of some taxi-way and approach lighting components might be questioned. An argument is presented for a 'building-blocks' review of the airport visual-aids system that could in some cases result in improved relationships between economy of display content and information value.

McKenna, J. T. (1998). Investigators Scrutinize Response to Close Call. *Aviation Week & Space Technology, 148*(24), 44-5(0005-2175).

Abstract: Federal officials are attempting to find out whether one or more FAA employees tried to stonewall probes into the near-collision of a DC-9 and Airbus A319 over the runway intersection at LaGuardia Airport on April 3. The National Transportation Safety Board and the FAA are studying the incident, and the Transportation Department inspector general is exploring the behavior of FAA officials during and after the near-collision. FAA officials and others involved in the

investigations stated the close call was caused by errors by the controller in the LaGuardia tower who was handling the aircraft, but pilots who fly regularly into the airport and people who work there said that the incident is symptomatic of the heavy workload, high traffic volume, and airport constraints at LaGuardia.

McKenna, J. T. (1999). FAA Aims to Revive Runway Safety Fight. *Aviation Week & Space Technology, 151*(18), 40-1(0005-2175).
Abstract: The FAA has established a new, centralized office with the aim of identifying ways of cutting the number of runway incursions and then taking steps to prevent such incidents. Cutting the number of runway incursions has been a chief goal of FAA since at least 1991; since 1993 both the number and rate of incursions have steadily increased. The new office will be headed by a director, John Mayrhofer, an air traffic official who has run key air traffic control facilities in New York and Southern California.

McKenna, J. T. (1999). FAA 'slow' to Address Runway Incursion Issue. *Aviation Week & Space Technology, 151*(5), 24-5(0005-2175).
Abstract: The FAA has failed to reverse the increasing incidence of near-collisions on airport runways and has budgeted little in terms of funds for measures to attain its aim of dramatically reducing the number of so-called runway incursions by 2000, the Transportation Department's inspector general (IG) has reported. The IG report, published on July 27, found that the FAA implemented plans to cut runway incursions in 1991, 1995, and again in October 1998. Nonetheless, the number and rate of incursions, in which an airplane, vehicle, or person moves onto a runway that is being used by a flight that is either departing or landing, has increased gradually since 1993, the report revealed.

McKenna, J. T. (2000). Runway incursions top U.S. air safety risks. *Aviation Week & Space Technology, 152*(5), 26-28.
Abstract: According to FAA officials, runway incursions pose the most serious threat to safe air travel; these have jumped by 75 percent since 1993. Because these accidents often involve two aircraft, they have the potential to kill twice as many people as other accident types; no clear technological means of addressing the problem have thus far emerged.

Meijer, R. (1998). Considerations on simulations to verify a system concept for improved airport guidance. In: *AIAA Modeling and Simulation Technologies Conference and Exhibit, Boston, MA, Aug. 10-12, 1998, Collection of Technical Papers* (pp. 500-508), Reston, VA & The Netherlands: American Institute of Aeronautics and Astronautics.
Abstract: This paper introduces a research program which aims at demonstrating a concept to allow the pilot to move the aircraft more efficiently under low visibility conditions than by visual means only. This concept comprises the exocentric, spatially integrated presentation of the taxiway relative to the current aircraft position on the aircraft's Electronic Flight Instrument System. The paper presents a preliminary system design that includes ground based and airborne systems. A simulation plan to verify assumptions, the concept, and the associated system design is discussed. A low-cost demonstrator which will be used to perform initial system verification is described. After this phase, implementation of the demonstrator in the Delft University laboratory aircraft is planned.

Mihalopoulos, D. (1999). Airport Plays Down "Runway Incursion" Danger Incidents Cited

by FAA Caused No Accidents, Griggs Says. *St. Louis Post - Dispatch*.
Abstract: Lambert Field is not so dangerous as a recent government report makes it appear, airport officials said Wednesday. "We're one of the safest airports in the nation," Lambert Director Leonard Griggs told the airport's board of commissioners at their meeting Wednesday afternoon at Lambert. Eight incursions were reported at Lambert last year, tying Newark International Airport in New Jersey for the second highest total. Only Los Angeles International Airport had more such incidents.

Miller, D. I. & Wolfman, G. J. (1993). Computer Human Interface Design in Tower Air Traffic Control for Aircraft Flight Data Management. In R. S. Jensen & D. Neumeister (Eds.) *Proceedings of the Seventh International Symposium on Aviation Psychology* (372a-372e).
Abstract: The Tower Control Computer Complex (TCCC) will introduce advanced workstations and software to the air traffic control tower. Work that was once performed with paper and pencil, knobs and dials, and task-specific computer systems will be managed from an individual's workstation. The most controversial and visible aspect of the TCCC has been the introduction of electronic flight data management to the tower. Flight data management is the vehicle by which tower controllers plan, track, and record aircraft movements. Failure to manage data properly can have serious consequences. An acceptable design must both limit time spent managing flight data, yet ensure accurate, timely, and visibly obvious actions on that data. This paper provides an overview of the TCCC computer-human interface (CHI) design for flight data management, and several associated issues. Of the five workstation input devices, three (speech recognition, touch screens, and a control grip device) have been included to perform specific flight data management tasks. The software design embodies predictable aircraft movements and controller actions as aircraft states which, in turn, provide a vehicle for tailoring the display of information to meet the current operator needs. State transitions provide a similar vehicle for editing, highlighting, and transferring flight data with minimal controller workload.

Miller, D. L., Wolfman, G. J., Mullins, R. T., & Crehan, C. (1994). Beyond the Bounds of the Human Factors Tool Kit: Computer-Human Interface Design in a Complex System. In *People and Technology in Harmony: Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, Volume 2*. Santa Monica, California: The Human Factors and Ergonomics Society.
Abstract: To achieve the potential of human factors involvement in computer-human interface design, human factors engineers must transition from being isolated specialists to integrated components of the mainstream life-cycle development process. A fundamental obstacle to this transition has been the limitations associated with traditional human factors methods. The search for better methods has resulted in a recent evolution in the human factors tool kit. While this evolution has increased tool kit utility, it is not yet as robust as needed for the development of complex systems. For the past several years the human factors team at Loral Federal Systems Company has been the central focus of system design and development activities for the Tower Control Computer Complex (TCCC). The TCCC will replace most Federal Aviation Administration airport tower cab equipment with advanced workstations and software. At least five limitations have been encountered with the traditional human factors tool kit due to the complexity of the TCCC and the environment in which it will be used. This paper describes these limitations, and the alternatives that have been successfully employed to produce an operationally suitable computer-human interface as part of an integrated life-cycle effort. At the heart of these remedies were the use of a dedicated team of representative end-

users and a variety of non-traditional design evaluation techniques, throughout the project life-cycle. Among these techniques was the evaluation of laboratory prototypes using a 'hands-off' intellectual review process and electronically supported group-based evaluations.

Miura, A., Morikawa, H., & Mizumachi, M. (1996). Air Traffic Control Data Tables for Conflict Alert System. ***Electronics and Communications in Japan Part I-Communications, 79*****(6), 101-113.**
Abstract: The conflict alert system was developed for air traffic control to detect and warn of the danger of aircraft collisions. This paper presents a configuration for air traffic control data tables that increases the efficiency of the conflict alert system, which was devised to predict what instructions to give for preventing collisions. Air traffic control data tables are constructed mainly from air route data and aircraft data. The aircraft are controlled by the air route unit, and all data as well as the relationships between the data (i.e., between aircraft, between aircraft and air routes, etc.) are updated continually in real time for the data tables in question. As a result: (1) the relationship between the aircraft and the air route can instantly be grasped, thereby improving the accuracy of the course prediction for the aircraft; and (2) when judging if two aircraft are possibly in conflict, the efficiency of the conflict detection process can be improved by rapidly being able to grasp the relative relationships of aircraft on adjacent air routes and the relationship between the leading and last aircraft on the same course. The feasibility of the points (1) and (2) is demonstrated through computer simulation.

Monan, W. P. (1983). ***Addressee errors in ATC communications: The call sign problem*** **(Report No. NASA-CR-166462. NAS 1.26:166462). Columbus, OH: Battelle Labs.**
Abstract: Communication errors involving aircraft call signs were portrayed in reports of 462 hazardous incidents voluntarily submitted to the ASRS during an approximate four-year period. These errors resulted in confusion, disorder, and uncoordinated traffic conditions and produced the following types of operational anomalies: altitude deviations, wrong-way headings, aborted takeoffs, go arounds, runway incursions, missed crossing altitude restrictions, descents toward high terrain, and traffic conflicts in flight and on the ground. Analysis of the report set resulted in identification of five categories of errors involving call signs: (1) faulty radio usage techniques, (2) call sign loss or smearing due to frequency congestion, (3) confusion resulting from similar sounding call signs, (4) airmen misses of call signs leading to failures to acknowledge or readback, and (5) controller failures regarding confirmation of acknowledgements or readbacks. These error categories are described in detail and several associated hazard mitigating measures that might be aken are considered.

Moody, C. (1991). Operational Evaluation of a Tower Workstation for Clearance Delivery. In R. S. Jensen (Ed.) ***Proceedings of the Sixth International Symposium on Aviation Psychology, Volume 1*** **(pp. 538-543).**
Abstract: At towered airports a function known as clearance delivery exists to provide the initial instrument flight rules (IFR) clearance to departing flights via voice radio. At busy airports the radio frequencies used for this function can become saturated at peak periods. To alleviate this problem the FAA has determined that this clearance information (referred to here as Predeparture Clearance or PDC) will be a service offered via a digital data link. The MITRE Corporation has developed an experimental tower workstation system which is used for issuing clearances in digital form. Three such workstations have been operationally evaluated at the Dallas/Ft.Worth, Chicago O'Hare and San Francisco Airports with the cooperation of several participating airlines. This paper describes the

experimental system and reports on experiences gained from field operation including results of surveys distributed to pilots and tower controllers using the system. As a result of positive response from the users, implementation of a national system based on the experimental system is now underway by the FAA.

Moore, J. G. (1991). ***Aviation safety runway incursions*****. Washington, D.C.: Congressional Research Service, Library of Congress.**
Abstract: Major studies and issue briefs of the Congressional Research Service. 1991-1992 supplement; reel 3. Includes bibliographical references.

Moore, M. (2000). Runway incursions: Awareness & prevention. Part 1. ***Air Line Pilot, 69*****(3), 16-17.**

Moorman, R. (1987). Stop, look, & listen: ALPA's Airports Standards and Air Traffic Control Committees focus on ways to reduce the increasing number of runway incursions. ***Air Line Pilot, 56*****(7), 18-22.**

Mordoff, K. F. (1986). Aeromexico Midair Hearing Highlights ATC Limitations. ***Aviation Week & Space Technology, 125*****,29-31.**

Mordoff, K. F. (1986). NTSB Study of DC-9 Crash Shows Piper in Area Without Clearance. ***Aviation Week & Space Technology,125,*** **45.**

Mordoff, K. F. (1986). Safety Board Completes Field Investigation of California Crash. ***Aviation Week & Space Technology,125,*** **36.**

Mundra, A. D., & Levin, K. M. (1990). Developing automation for terminal air traffic control: Case study of the imaging aid. In ***Engineering Inst. of Canada, Canadian Conference on Electrical and Computer Engineering, Volumes 1 and 2*** **(4 p) (SEE N93-30215 11-31)**
Abstract: A passive automation aid called the imaging aid or ghosting aid has recently been developed for the US Federal Aviation Administration to help air traffic controllers stagger aircraft to converging runways in instrument flight rule conditions. This aid has been prototyped in a real-time simulation facility with the help of full performance level controllers, has been approved for operational evaluation at Lambert St. Louis International Airport during 1990, and is expected to be deployed nationally in the USA starting in 1992. The prototyping process used in the development of the imaging aid is described as a case study in developing air traffic control (ATC) automation. In this process, the imaging aid was designed to solve the difficulty of precise staggering on a susdology is proposed for the development of automation for terminal ATC based on the lessons learned from this prototype. (Author (CISTI))

Myers, S. L. (1992). Jet Aborts Landing, Averting Collision Above La Guardia. ***New York Times Current Events Edition*****.**
Abstract: A plane landing at La Guardia Airport in New York on May 20, 1992 narrowly avoided colliding with another aircraft taking off on the same runway. An investigation is being made into whether pilot error or air traffic controllers were to blame.

National Aeronautics and Space Administration (1998). ***Airport Surface Operations Safety Action Plan, 1998: To Reduce Runway Incursions and Improve Operations*** **(Report**

No. NASA no. 19990009856. PB99-112559). Washington, D.C.: NASA.
Abstract: This 1998 Action Plan represents a systemwide, multifaceted strategy to reduce incidents and accidents directly attributable to runway incursions and improve airport surface operations. It identifies goals, objectives, and actions that address management and procedural changes; improvements in airport navigation aids, signs and surface markings; technology-based efforts; and increased incursion awareness efforts. The plan is in direct support of the FAA Administrator's goal to reduce runway incursions by 15 percent of the 1997 level by the year 2000.

National Transportation Safety Board (1986). ***Special investigation report: Runway incursions at controlled airports in the United States*** **(Report No. PB86-917003. NTSB/SIR-86/01) Washington, D.C.: The Board; National Technical Information Service.**

National Transportation Safety Board (1991). ***Aircraft accident report: Runway collision of Eastern Airlines Boeing 727, flight 111 and Epps Air Service Beechcraft King Air A100, Atlanta Hartsfield International Airport, 18 January 1990*** **(Report No. PB91-910403. NTSB/AAR-91/03) Washington, D.C.: National Transportation Safety Board.**
Abstract: The runway collision of an Eastern Airlines Boeing 727 with an Epps Air Service Beechcraft at the Hartsfield International Airport, Atlanta, GA, on January 8, 1990, is examined. The safety issues discussed are air traffic controller procedures, conspicuity of airplane lighting, the see and avoid concept, and equipment and systems to prevent runway incursions. Safety recommendations concerning these issues were made to the FAA.

National Transportation Safety Board (1991). ***Aircraft accident report: Northwest Airlines, Inc., Flights 1482 and 299. Runway incursion and collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990*** **(Report No. PB91-910405. NTSB/AAR-91/05). Washington, D.C.: National Transportation Safety Board.**
Abstract: The runway collision of two Northwest Airlines aircraft on a runway at the Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, on December 3, 1990 is explained. The safety issues discussed are airport marking and lighting, cockpit resource management, air traffic control procedures in low visibility conditions, flight attendant procedures during evacuations, and the design of the DC-9 tailcone emergency release system. Safety recommendations concerning these issues were made to the Federal Aviation Administration, the Detroit Metropolitan/Wayne County Airport, and Northwest Airlines, Inc. (Author)

National Transportation Safety Board (1995). ***National Transportation Safety Board Aircraft Accident Report: Runway Collision Involving Transworld Airlines Flight 427 and Superior Aviation Cessna 441, Bridgeton, Missouri, November 22, 1994*** **(Report No. NASA no. 19980017561. PB95-910405. NTSB/AAR-95/05). Washington, D.C.: National Transportation Safety Board.**
Abstract: This report explains the runway collision of Trans World Airlines flight 427, a McDonnell Douglas DC-9-82, and N441KM, a Cessna 441, at the intersection of runway 30R and taxiway Romeo at the Lambert-St. Louis International Airport in Bridgeton, Missouri. The safety issues discussed in the report include aircraft lighting and conspicuity; airport markings, signs, and lighting; runway 31 designation, utilization, displaced threshold; ATC and pilot phraseology (specifically, the term 'back-taxi'); pilot

training, runway incursion detection/prevention methods; and ASDE/AMASS development. Safety recommendations concerning some of these issues were made to the Federal Aviation Administration (FAA).

Nordwall, B.D. (1989). Norden Develops System to Warn Controllers of Runway Incursions. ***Aviation Week & Space Technology, 130,*** **28.**

O'Driscoll, P. (1998). FAA to Probe Jetliner's Close Call. ***USA Today,*** **(0734-7456).**
Abstract: But air traffic controllers and Southwest Airlines, whose jetliner was about to land last Friday when its anti-collision alarm sounded, differ sharply about how serious the incident was. The controllers say the warning device actually led the airliner into danger. Southwest Flight 1451, carrying 58 passengers Jan. 9 from Las Vegas to Burbank-Glendale-Pasadena Airport, was on final approach at 10:50 a.m., about 10 miles west of the runway. Suddenly, the 737-300 jet's collision warning system ordered a steep, 1,600-foot climb. The pilot's evasive maneuver took the eastbound airliner into the path of a twin-engine Cessna 402 air taxi, cruising south at 4,000 feet. The jet also approached an Ameriflight Beech 99 cargo plane flying west at 5,000 feet.

Obradovich, J. H., Smith, P. J., Denning, R., Chapman, R., Billings, C., McCoy, E., & Woods, D. D. (1998). Cooperative Problem-Solving Challenges for the Movement of Aircraft on the Ground. In Human-System Interaction: The Sky's No Limit. In ***Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Volume 1*** **(pp. 57-61). Santa Monica, California: The Human Factors and Ergonomics Society.**

Olcott, J. W. (1984). Adiz Intercept. ***Business and Commercial Aviation, 55,*** **102.**

Olcott, J. W. (1986). A Tragic Case of "See and Avoid". ***Business and Commercial Aviation,58,*** **76.**

Olcott, J. W. (1986). What's Happening With ATC?. ***Business and Commercial Aviation, 58,*** **44-9.**

Olcott, J. W. (1987). Converging Paths. ***Business and Commercial Aviation, 60,*** **96.**

Olcott, J. W. (1987). Failures Over Cerritos. ***Business and Commercial Aviation, 61,*** **98.**

Olcott, J. W. (1988). When Radar Appears Blind. ***Business and Commercial Aviation, 62,*** **118.**

Ott, J.(1996). Crash Probe Considers Safety at Small Airport. Ill. ***Aviation Week & Space Technology,145,*** **33(0005-2175).**
Abstract: The safety implications of operating commercial flights into the small municipal airport at Quincy, Illinois, will be considered in an NTSB investigation of a fatal collision of two aircraft there on November 19, 1996. A United Express Beech 1900 and a Beech King Air 90 collided at the intersection of Runways 4 and 13, destroying both planes and killing 14 people. According to George Black, the NTSB official in charge of the investigation, the focus of concern is that the airport was not attended by fire and rescue squads.

Oving, A., Vanbreda, L., & Werkhoven, P. (1998). ***Effect of Three-Dimensional and Mono Auditory Information on Performance in Cockpit Warning Tasks,<ORIGINAL TITLE> Effecten van Drie-Dimensionaal en Mono Geluidsinformatie op de Prestatie ten Aanzien van Waarschuwingen in de Cockpit*** **(Report No. NASA no. 19990027096. TD98-0264. TM-98-A054). Soesterberg, Netherlands: Institute for Human Factors TNO, Research Inst.**

Abstract: The potential benefits of a three-dimensional (3D) auditory display in conveying directional information were investigated in a flight simulation experiment. The study was aimed at the application of 3D audio in the cockpit of civil aircraft. Participants were required to follow a specific flight path in a runway approach. Standard cockpit information was available on a set of visual displays, i.e., primary flight information, flight path and tracking information, traffic alert and collision avoidance information (TCAS) and on-board systems status information. In the experiment, additional auditory directional information was presented for TCAS-warnings or for warnings of system failures in the aircraft. In case of a TCAS-warning, participants were required to identify the specific orientation of the target aircraft with respect to the outside world. In case of a failure warning, participants had to indicate the location of the failure in the aircraft itself. Warnings were always presented both aurally and visually. There were four conditions for the presentation of directional information in the aural warnings: mono-sound with or without verbal directional statements and 3D-sound with or without verbal directional statements. The verbal directional statements in the TCAS-warning referred to a specific quadrant of the outside world in the TCAS task (e.g., lower quadrant left) and to the specific side of the aircraft for system failures (e.g., left-hand or right-hand side). The 3D auditory display used a head-track ng device to make the external position of the source invariant under head movements. In all conditions, directional information for the warnings was presented on a visual display as well. Results showed that for the TCAS task and the failure task, addition of directional information (i.e., 3D-sound or verbal directional information) resulted in significantly reduced response times. The response times were shortest when both types of directional information were combined in the TCAS-warning. For the system failure task, only the differences between the response times in the mono-without condition and the three other conditions proved to be significant.

Pettyjohn, F. S., White, J. T., Mitchell, R. E., Lilienthal, M. G., Sullivan, H. H., & Williams, R. E. (1987). Short Pr and Normal Qrs - Aeromedical Relook. ***Aviation Space and Environmental Medicine, 58*****(5), 485.**

Phillips, E. H. (1997). NTSB Faults Pilots for Illinois Airport Collision. ***Aviation Week & Space Technology, 147*****, 41-2.**

Abstract: According to the U.S. National Transportation Safety Board (NTSB), the fatal collision of a Beechcraft King Air A90 and a United Express Beechcraft 1900C at Quincy, Illinois, on November 19, 1996, was caused by the King Air pilots' failure to use proper communications and "see-and-avoid" procedures at an uncontrolled airport. In the course of their probe into the collision, investigators also found that the radio transmissions from the 1900C were of "faint and poor quality" and caused difficulty in establishing what was actually said, noted the NTSB. Various recommendations made by the board to the FAA are discussed.

Phillips, E. H. (1997). Radio Procedures Key Factor in NTSB Quincy Investigation. ***Aviation Week & Space Technology, 146,*** **48-9.**

Abstract: A National Transportation Safety Board investigation into the November 1996

runway collision of a United Express Raytheon 1900C and a Beechcraft King Air A90 at Quincy, Illinois, is discussed. Three principal factors in the crash, which resulted in the deaths of 14 people, are examined: dusk conditions, uncontrolled airport radio procedures, and an inability to open aircraft exit doors.

Phillips, D. (1991). FAA Expedites Runway Safety Plan. *The Washington Post,* (0190-8286).
Abstract: The FAA, faced with three airline crashes involving runway "incursions" within 13 months, has decided to expedite plans to seek ways to prevent such incidents.

Phillips, D. (1998). Air Traffic Errors up 20 Pct., FAA Says; Controller Miscues Are Highest in N.Y. *The Washington Post,* (0190-8286).
Abstract: In airport control towers across the nation, where controllers handle numerous complicated aircraft movements, these lapses often involved visual misjudgments, leading in one case to an April 3 near-midair collision at La Guardia Airport in New York, according to internal Federal Aviation Administration documents made available by aviation sources. The sharp upswing in controller mistakes played a part in the FAA's recent decision to order the retraining of 10,000 of the nation's 18,000 controllers. The agency took action after the La Guardia incident, when an Air Canada Airbus A-319 taking off for Toronto nearly collided with a US Airways DC-9 landing from Columbus, Ohio. The two aircraft came as close as 20 feet after a controller apparently waited too long to order the US Airways plane to abort its landing on a cross runway. The FAA documents showed the error rates were the highest in the New York region, with tower operations making 1.69 errors per 100,000 operations at La Guardia Airport and 1.38 errors at John F. Kennedy Airport. The New York regional control center, which handles flights entering the New York airspace, also had the highest error rate, 1.98, compared with a national average of 0.55.

Phillips, D. (1998). Near-Collision Spurs Air Traffic Retraining. *The Washington Post,* (0190-8286).
Abstract: Federal regulators have ordered the retraining of 10,000 air traffic controllers nationwide after two passenger jets came as close as 20 feet from hitting each other over New York's La Guardia Airport. The previously unreported April 3 incident, coupled with an increase in controller errors nationwide, prompted the Federal Aviation Administration to order mandatory proficiency training for controllers working in airport towers handling takeoffs and landings, said Ronald E. Morgan, the FAA's acting associate administrator for air traffic services. Investigators said their probe has convinced them that it was nearly a miracle the two jets did not collide. An Air Canada Airbus A320 jet, taking off from La Guardia, flashed directly over a US Airways DC-9 jet as it broke off a landing attempt.

Phillips, D. (1999). Runway Safety Program Delayed; FAA Radar System Hits Bureaucratic, Technical Snags. *The Washington Post,* (0190-8286).
Abstract: In the decade since the Federal Aviation Administration announced plans for a system to warn air traffic controllers of possible runway collisions, 59 people have died in five runway crashes while near- collisions have increased yearly. But the FAA's major radar software program to help prevent conflicts between aircraft on the ground, originally scheduled for deployment in 1992, has been delayed at least another two years -- until 2002. And officials said it may never live up to some of its original promise, including warning of conflicts on taxiways or potential collisions with trucks and other support equipment. Meanwhile, runway "incursions" -- FAA jargon for aircraft, vehicles or people bumbling into places for which they have no clearance -- continue to increase

steadily, rising from 186 in 1993 to 325 in 1998. About 56 percent are "pilot deviations," while the rest are either "operational errors" laid to controllers, or vehicles and pedestrians who enter restricted areas.

Phillips, E. H.. (1995). FAA BANS NIGHTTIME POSITION-HOLD CLEARANCES. ***AVIATION WEEK & SPACE TECHNOLOGY, 3*** **(13).Abstract:** ACTION FOLLOWING NOVEMBER 1994 RUNWAY INCURSION ACCIDENT AT ST. LOUI S.

Pianalto, G. & Vian, J. (1997). Synthetic Vision System for Low Visibility Airport Surface Movement. In M. Mouloua and J.M. Koonce (Eds.), ***Human-Automation Interaction: Research and Practice.*** **New Jersey: Lawrence, Erlbaum, Mahwah,**

Pilley, H. R., & Pilley, L. (1993). GPS in the airport environment - Runway incursion avoidance using GPS. In: ***ION GPS-93; Proceedings of the 6th International Technical Meeting of the Satellite Division of the Institute of Navigation, Salt Lake City, UT, Sept. 22-24, 1993. Vol. 2*** **(p. 911-918), Washington, DC,: Institute of Navigation.**

Abstract: Based on the integration of enhanced GPS with highly accurate 3D airport maps, the Airport Control & Management (AC&M) System has the capability to provide all-weather air and ground navigation and control for a variety of vehicles within the airport terminal area. Real time collision prediction algorithms, based on the GPS inputs, are used to alert the pilot and Air Traffic Controller of potential incursions, collisions, and off-course conditions. The AC&M methodology supports the participation of various vehicle types. Each vehicle can receive real-time differential corrections and transmitting GPS-based information. The enhanced GPS-based Position, Velocity, and Time (PVT) information derived on board each vehicle is used to support mathematical algorithms compatible with airport movement and management operations. A key element of the Airport Control/Management System is the integration of GPS-based position data with a 3D digital airport map.

Pilley, L. V., & Pilley, H. (1994). DGPS for seamless airport operations. In: ***ION GPS-94; Proceedings of the 7th International Technical Meeting of the Satellite Division of the Institute of Navigation, Salt Lake City, UT, Sept. 20-23, 1994. Pt. 1*** **(p. 913-921), Alexandria, VA: Institute of Navigation.**

Abstract: This paper describes the prototype GNSS/ADS-based seamless airport navigation, control, and management system developed by Deering System Design Consultants, Inc. (DSDC) at the Manchester, NH airport. Beginning with the earliest GPS-based airport surface operation tests, DSDC's efforts have broadened to include DGPS-based precision approach and runway incursion/collision avoidance for air and ground vehicles. The results of these ongoing tests have shown the strengths and versatility of an integrated DGPS/data link system. Using local differential corrections broadcast to surface vehicles and aircraft, the following airport functions have been successfully demonstrated: ADS-based situational awareness at ATC; ADS-based situational awareness in vehicles; collision detection (ATC and vehicles); 3D runway and zone detection (ATC and vehicles); precision approach and map navigation (vehicles); mirrored navigation at ATC; and automated lighting control based on vehicle position and clearance status. This paper discusses the techniques used in DSDC's research efforts and the benefits of a DGPS-based system for future airport navigation and surveillance. (Author)

Pope, J. A. (1990). The airport side of runway incursions. *Air Line Pilot, 59*(11), 22-26.

Pope, K. (1992). It's a Nice Place to Take a Drive, Except for All Those Pesky Planes. *Wall Street Journal,* (0099-9660).

Abstract: The security problem at Meacham Field, a local corporate airport in Fort Worth TX, is discussed. The FAA says there have been at least 20 runway incursions in the past month. In a recent instance, an elderly woman out for a drive caused a delay in the landing of a twin-engine plane.

Pritchett, A. (1997). Pilot non-conformance to alerting system commands during closely spaced parallel approaches. *Dissertation Abstracts International: Section B: The Sciences.*

Abstract: (Cockpit alerting systems monitor potentially hazardous situations, both inside and outside the aircraft. When a hazard is projected to occur, the alerting system displays alerts and/or command decisions to the pilot. However, pilots have been observed to not conform to alerting system commands by delaying their response or by not following the automatic commands exactly. This non-conformance to the automatic alerting system can reduce its benefit. Therefore, a need exists to understand the causes and effects of pilot non-conformance in order to develop automatic alerting systems whose commands the pilots are more likely to follow. These considerations were examined through flight simulator evaluations of the collision avoidance task during closely spaced parallel approaches. This task provided a useful case-study because the effects of non-conformance can be significant, given the time-critical nature of the task. A preliminary evaluation of alerting systems identified non-conformance in over 40% of the cases and a corresponding drop in collision avoidance performance. A follow-on experiment found subjects' alerting and maneuver selection criteria were consistent with different strategies than those used by automatic systems, indicating the pilot may potentially disagree with the alerting system if the pilot attempts to verify automatic alerts and commanded avoidance maneuvers. A final experiment found supporting automatic alerts with the explicit display of its underlying criteria resulted in more consistent subject reactions. In light of these experimental results, a general discussion of pilot non-conformance is provided. Contributing factors in pilot non-conformance include a lack of confidence in the automatic system and mismatches between the alerting system's commands and the pilots' own decisions based on the information available to them. The effects of non-conformance on system performance are discussed. Possible methods of reconciling mismatches are given, and design considerations for alerting systems which alleviate the problem of non-conformance are provided. (Copies available exclusively from MIT Libraries, Rm. 14-0551, Cambridge, MA 02139-4307. Ph. 617-253-5668; Fax 617-253-1690.) ((c) 1999 APA/PsycINFO, all rights reserved)

Pritchett, A. R. (1999). PILOT PERFORMANCE AT COLLISION AVOIDANCE DURING CLOSELY SPACED PARALLEL APPROACHES. *AIR TRAFFIC CONTROL QUARTERLY: AN INTERNATIONAL JOURNAL OF ENGINEERING AND OPERATIONS, 7*(1), 74-75.

Pritchett, A. R. (2000). Display effects on shaping apparent strategy: a case study in collision detection and avoidance. *International Journal of Aviation Psychology,* 59-83.

Abstract: (Examined Ss behavior at collision detection and avoidance during parallel approaches and tested how it was affected by additional information on traffic displays. Ss behavior was analyzed by looking for "apparent strategies," measured by

characteristics of Ss actions that remain consistent across a variety of scenarios; likewise, collision avoidance maneuvers with a "turn-away" component were consistently chosen for all scenarios. 19 Ss, comprised of pilots and nonpilots, flew the experiment. Unfortunately, these apparent strategies did not have adequate performance. Although some statistically significant differences in measures of participant behavior were found between display conditions, they were not substantial enough to increase performance. ((c) 2000 APA/PsycINFO, all rights reserved)

Pritchett, A., Carpenter, B., Asari, K., Kuchar, J., & Hansman, R. (1995). ***Issues in airborne systems for closely-spaced parallel runway operations. In: AIAA/IEEE Digital Avionics Systems Conference (DASC), 14th, Cambridge, MA, Nov. 5-9, 1995, Proceedings*** **(p. 140-145), New York: Institute of Electrical and Electronics Engineers, Inc.**

Abstract: Efforts to increase airport capacity include studies of aircraft systems that would enable simultaneous approaches to dosely spaced parallel runways in Instrument Meteorological Conditions (IMC). The time-critical nature of a parallel approach results in key design issues for current and future collision avoidance systems. These issues are being studied in two ways. First, a part-task flight simulator stndy has examined the procedural and display issues inherent in such a time-critical task. Second, a prototype collision avoidance logic capable of generating this maneuver guidance has been designed using a recently developed methodology.

Rankenburg, J. (1997). The Wake Vortices Warning System (WVWS) for Frankfurt Airport Parallel Runway System 25 (NASA No. 19980073311). ***Proceedings of the NASA First Wake Vortex Dynamic Spacing Workshop*****. Munich, Germany: Flugwissenschaftliche Forschungsanstalt.**

Abstract: The WVWS objective is to reduce/suspend increased wake vortex separation minima between staggered aircraft on final approach to the two parallel runways 25 at Frankfurt airport in order to increase arrival capacity whilst maintaining or increasing safety. Aircraft approaching the same runway will continue to be separated according to the increased (ICAO) wake vortex separation minima. Issues and analysis supporting this objective are presented.

Rankin, J. M. (1994). Differential GPS and system integration of the Low Visibility Landing and Surface Operations (LVLASO) demonstration: Abstract Only. In ***Hampton Univ., 1994 NASA-HU American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program*** **(p 100) (SEE N95-23276 07-99).**

Abstract: The LVLASO Flight Demonstration of ASTA concepts (FDAC) integrates NASA-Langley's electronic moving map display and Transport Systems Research Vehicle (TSRV) (a modified Boeing 737 aircraft); ARINC's VHF data link, GPS ground station, and automated controller workstation; and Norden's surface radar/airport movement safety system. Aircraft location is shown on the electronic map display in the cockpit. An approved taxi route as well as other aircraft and surface traffic are also displayed. An Ashtech Z12 Global Positioning System (GPS) receiver on the TSRV estimates the aircraft's position. In Differential mode (DSPS), the Ashtech receiver accepts differential C/A code pseudorange corrections from a GPS ground station. The GPS ground station provides corrections up to ten satellites. The corrections are transmitted on a VHF data link at a 1 Hz. rate using the RTCM-104 format. DGPS position estimates will be within 5 meters of actual aircraft position. DGPS position estimates are blended with position, velocity, acceleration, and heading data from the TSRV Air Data/Inertial Reference System (ADIRS). The ADIRS data is accurate in the

short-term, but drifts over time. The DGPS data is used to keep the ADIRS position accurate. Ownship position, velocity, heading, and turn rate are sent at a 20 Hz. rate to the electronic map display. Airport traffic is detected by the airport surface radar system. Aircraft and vehicles such as fuel trucks and baggage carts are detected. The traffic's location, velocity, and heading are sent to the TSRV. To prevent traffic symbology from jumping each second when a location update arrives, velocity and heading are used to predict a new traffic location for each display update. Possible runway incursions and collisions can be shown on the electronic map. Integrating the different systems used in the FDAC requires attention to the underlying coordinate systems. The airport diagram displayed on the electronic map is obtained from published navigational charts. The charts reference the North American Datum of 1927 (NAD27) or a local state-plane coordinate system. GPS uses the World Geodetic Standard of 1984 (WGS84). Both NAD27 and WGS84 model the Earth as an ellipsoid, however, they use a different origin and different size ellipsoids. Latitudes and longitudes given in these systems can be converted to a Cartesian system with the origin at the Earth's center. The surface radar detects traffic in a locally-level, rho-theta coordiante system. The electronic airport diagram is stored using a flat XY coordinate system. The map origin is at the tower and is referenced as True North up. All ownship and other traffic positions must be converted to the electronic map's frame of reference for display.

Reynolds, M., Neumeier, M., Mitman, R. & Rehmann, A. (1995). ***Flight deck automation - Problems and concerns as reported in the Aviation Safety Reporting System. In: SAE 1994 Transactions, Journal of Aerospace. Section 1 - Vol. 103*** **(p. 1944-1951), Warrendale, PA: Society of Automotive Engineers, Inc.**

Abstract: Aviation Safety Reporting System (ASRS) reports were analyzed to identify flightdeck operational problems related to aircraft automation systems, particularly those problems that may be exacerbated by the addition of data link systems. Four major automation problem groups were discovered (automation failure, programming errors, distraction-programming, and mismanagement-confusion). Also, several automation-induced errors were identified (e.g., runway incursions and altitude deviations). The reports are classified by attributes such as automation system and flight error. Each automation group is discussed, and based on a limited sample of reports, conclusions are drawn; with respect to data link, potential positive and negative impacts are described.

Richfield, P. (1999). Runway Incursion Program Criticized. ***Business & Commercial Aviation, 85*****(3), 37(0191-4642).**

Abstract: Criticism of the runway incursion prevention program of the Federal Aviation Administration (FAA) is discussed. A report from the Department of Transportation's Office of the Inspector General states that runway incursions have risen by 11 percent through 1998 and that the FAA program has been ineffective in tackling the problem. The FAA had pledged to reduce incursions by 15 percent by the year 2000 but is considered unlikely to meet this goal.

Rosenberg, B. (1999). AIRPORT GROUND SAFETY. NEW INITIATIVES FOR A RECURRING PROBLEM. ***Airports Today, 2*****(2), 9-13.**

Abstract: The Federal Aviation Administration (FAA) defines a "runway incursion" as any occurrence at an airport involving an aircraft, vehicle, person or object on the ground which creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing or intending to land. Over the past four years, the incidents of runway incursions have increased by 25%. Historical data shows that runway incursions generally occur at large, high volume airports and more often than not involve

general aviation pilots and misunderstandings between pilot and ground control instructions. To address a growing and potentially dangerous problem, the FAA's latest plan is the third stage in a decade long effort to improve the situation. Earlier emphasis was to improve pavement markings and implement international standard signage at all Part 139 air carrier airports which is now done. The FAA is now deploying Airport Surface Detection Equipment (ASDE) radar and Airport Movement Area Safety Systems (AMASS) software systems which are able to provide a computer generated map of airport runways, taxiways, and service areas and display visual and audible warnings of potential conflicts.

RUNWAY INCURSIONS. (1997). ***FAA AVIATION NEWS, 11*****.**

Sachs, G., Moller, H., & Dobler, K. (1994). Synthetic vision and precision navigation for aircraft taxi guidance in low visibility. ***In the Proceedings of the American Institute of Aeraunotics and Astronotics, Guidance, Navigation and Control Conference.*** **Scottsdale, AZ.**
Abstract:

Schaefer, B. (1993). Enhanced vision systems in airbus aircraft. In: ***Looking ahead; Proceedings of the International Symposium on Head Up Display, Enhanced Vision and Virtual Reality, Amsterdam, Netherlands, Oct. 25, 26, 1993*** **(3p.), Amsterdam, Netherlands: Association of Aeronautical Engineers.**
Abstract: To avoid operational problems or, worse, a degradation of flight safety, the introduction of EVSs (Enhanced Vision Systems) into routine airline operations of Airbus aircraft, tasks to be fulfilled by the systems or the goals that are expected to be achieved when using the system were defined. EVS is expected to improve operation in low visibility conditions and at night. While EVS might be helpful during approaches in CAT I or better meteorological conditions (for example to visually acquire the runway and facilitate the lateral navigation during a nonprecision approach), the real benefit is expected in weather conditions below CAT I, when the visual cues as provided by the human eyes might be insufficient for a manual final approach and landing. Obviously, these goals have to be achieved without endangering flight safety. The price of the system and the training requirement for the crew must be reasonable and should preferably be offset by reduced operational costs due to an improved all weather capability or a reduced number of diversions.

Schneiderman, R. (1991). Aging ATC radars beg for upgrades. ***Microwaves & RF, 30,*** **33, 34, 37 (4 ff.).**
Abstract: The current status of FAA programs for upgrading airport ATC radar equipment is surveyed from an electronics industry perspective. A number of program delays are discussed, and it is suggested that they may lead to business opportunities for firms in the HF hardware sector. Particular attention is given to phased-array antenna systems for monitoring traffic on the ground, runway-incursion management systems, recent accidents involving ground collisions, delays in implementation due to antenna problems, proposed improvements in long-range en route radars, and continuing disagreements with respect to the transmission system for digital ATC messages. (D.G.)

Shuch, H. P. (1992). The influence of flight experience on midair collision risk perception. ***Accident Analysis & Prevention,*** **655-660.**
Abstract: (Pilot complacency, arising from a history of incident-free flights, plays a role

in the midair collision process. Pilot risk perception is explored using Laplace's Law of Succession, and the resulting perceived collision probability compared to reality. The 2 converge at around 5,000 hrs of flight experience. The influence of prior pilot experience on traffic scanning vigilance is discussed. ((c) 1999 APA/PsycINFO, all rights reserved)

Smith, K., Knecht W., & Scallen S. F. (1998). An Index of Dynamic Density. *Human Factors, 40*(1), 69-78(0018-7208).

Abstract: The risk of a collision between aircraft is rising as the density of commercial air traffic increases. This trend, together with the overwhelming need to upgrade the National Airspace System, has motivated the Federal Aviation Administration to sponsor the development of metrics to evaluate "dynamic density" - a proxy for the likelihood of collision risk. Here we propose and evaluate a mathematical index of dynamic density, D, that describes collision risk. Although our domain of investigation is aviation, the logic of D is applicable whenever objects move in limited spaces. A series of sensitivity analyses illustrate how D responds to frequently encountered air traffic conflict situations. We illustrate a use of D that characterizes pilot performance and efficiency in experimental simulations of free flight and suggest other human factors applications. This research could be applied immediately by the traffic management units of en-route air traffic control centers to reformulate the criterion for the critical capacity of sectors. Reprinted by permission of the publisher.

Sorkin, M. D., & McDermott K. (1996). Runway Collision Kills 14 in Illinois. *St. Louis Post - Dispatch.*

Abstract: A small plane from St Louis trying to take off from the airport in Quincy IL on Nov 19, 1996 collided with a larger commuter aircraft that was landing. All 14 aboard both planes died.

Speijker, L. J., Couwenberg, M. J. H., & Kleingeld, H. W. (1997). Collision Risk Related to the Usage of Parallel Runways for Landing (Report No. PB2000-100026/XAB. NLR-TP-97183-U). Amsterdam, Netherlands: National Aerospace Lab.

Abstract: Due to space limitations at most airports an increased airport capacity can often only be accomplished by using existing parallel runways more effectively or by building additional parallel runways. This study focuses on the collision risk related to independent parallel approaches and the minimum required parallel runway spacing for which the collision risk may be judged acceptable. The suitability of several risk measures and methods for Target Level of Safety (TLS) assessment is studied. Application of two methods provide a TLS-area, defining a range from which the TLS may be chosen by policy makers. A risk model is developed for determination of the collision risk between aircraft conducting independent parallel approaches under Instrument Meteorological Conditions (IMC), thereby using Instrument Landing System (ILS) procedures. Numerical evaluations show that the collision probability between two aircraft can be considerable under various operational conditions, especially near turn on to the localizer and during a dual missed approach. For trying to maintain the collision risk at a low and acceptable level, three risk reducing measures are identified. Provided that these measures are applied and assuming that a TLS from the specified TLS-area is used, independent parallel approaches may be judged adequately safe if the runway spacing is greater than 1270 m, and unsafe if the spacing is lower than 930 m.

Sridhar, B., & Chatterji, G. (1994). Computer-aided system for detecting runway incursions. In: *Sensing, imaging, and vision for control and guidance of aerospace vehicles; Proceedings of the Conference, Orlando, FL, Apr. 4, 5, 1994, SPIE*

Proceedings. Vol. 2220 **(p. 328-337), Bellingham, WA: Society of Photo-Optical Instrumentation Engineers.**
Abstract: A synthetic vision system for enhancing the pilots ability to navigate and control the aircraft on the ground is described. The system uses the onboard airport database and images acquired by external sensors, such as millimeter wave, infrared, and low-light TV cameras. Additional navigation information needed by the system is provided by the Inertial Navigation System and the Global Positioning System. The various functions of the system, such as image enhancement, map generation, obstacle detection, collision avoidance, guidance etc., are identified. The available technologies applicable to the aircraft ground navigation problem are noted. Example images of a truck crossing the runway while the aircraft flies close to the runway centerline are described. (Author)

Steenblik, J. A. (1996). TWA FLIGHT 427 RUNWAY INCURSION. ***AIR LINE PILOT,65*****(1), 20-24.**

Steyer, R. (1997). Lambert Field Is Safe Despite `Incursions,' Griggs Says. ***St. Louis Post - Dispatch.***
Abstract: Their comments follow by one day a report in the newspaper USA Today showing that Lambert had one of the highest number of airport collision hazards for the 12 months that ended September 30. The USA Today article "does not necessarily place Lambert's activities inthe proper perspective when comparing us with some much smaller U.S. airports," said Leonard L. Griggs Jr., airports director at Lambert Field. "We think Lambert is a safe airport," said Keith O'Leary, communications chairman for the Trans World Airlines branch of the Air Line Pilots Association. "We would like to see improvements made. Lambert could benefit from another runway."

Suleimanov, N. T. (1981). Imitative Modeling of Aircraft Collisions. ***Izvestiya Vysshikh Uchebnykh Zavedenii Aviatsionaya Tekhnika, 2*****, 95-97.**

Sullivan, A., & Curry, M. (1999). Runway Incursion Reduction Program - Dallas/Ft. Worth Demonstration/Validation Project. In: ***Gateway to the new millennium; Proceedings of the 18th Digital Avionics Systems Conference (DASC), Saint Louis, MO, Oct. 24-29, 1999. Vol. 1*** **(p. 5.D.4-1 to 5.D.4-51), Piscataway, NJ: Institute of Electrical and Electronic Engineers, Inc.**
Abstract: Dallas-Ft. Worth International Airport (DFW) has been chosen to host the activities of the Runway Incursion Reduction Program (RIRP). This paper describes the RIRP DFW surveillance system and summarizes the overall plan for demonstrating and validating the RIRP DFW system. (AIAA)

Theunissen, D. (1998). Structured specification of exocentric frames of reference. ***In the Proceedings of the American Institute of Aeraunotics and Astronotics, Modeling and Simulation Technologies Conference and Exhibit*****, Boston, MA.**

U.S. AVIATION RUNWAY-INCURSION RATES AND NEAR-MIDAIR COLLISION RATES SHOW UPWARD TREND (1998). ***FLIGHT SAFETY DIGEST, 17*****(1), 23-25.**
Abstract: SUBTITLE: THE RATE OF RUNWAY INCURSIONS AT U.S. AIRPORTS HAS INCREAS ED STEADILY SINCE 1993.

Wagenmakers, J. (1991). ***Aircraft performance engineering.*** **New York: Prentice Hall.**

Abstract: The present volume gives attention to those aspects of aircraft performance engineering related to the safe and economic operation of commercial aircraft fleets, emphasizing issues which are either not generally appreciated or warrant further study. Among the topics discussed are airworthiness and certified performance, operation on wet and contaminated runways, takeoff performance and obstacle clearance, aircraft noise problems, and extended-range operation with two-engine aircraft. Also discussed are fuel conservation, aircraft performance monitoring, performance computers and flight-management systems, weight/balance management, and professional organizations' responsibilities for performance engineering-related developments.

Wald, M. L. (1995). Crash Cited at a Hearing on Runway Risk. ***New York Times Current Events Edition.***

Abstract: As part of its investigation of "runway incursions," cases in which a moving object gets in the way of a plane landing or taking off, the NTSB heard testimony on Apr 19, 1995 on the fatal Nov 22, 1994 accident at the St Louis airport in which a TWA jet hit a twin-engine Cessna that was sitting on a runway.

Wald, M. L. (1997). Board Cites Pilots' Actions as Responsible for Deadly Collision. ***New York Times,*** **(0362-4331).**

Abstract: A United Airlines commuter aircraft collided with a private plane on a runway in Illinois last November because the private pilot waited on the ground for more than a minute after announcing his departure and did not answer a radio call from the arriving commuter flight, the National Transportation Safety Board said today. But the safety board also found that a third plane, flown by a pilot barely out of training, had contributed to the accident in Quincy, Ill., by making an ambiguous transmission. A man on the plane radioed that he would wait to take off, but he did not completely identify his plane, so the United flight may have misunderstood which plane was waiting. Quincy's airport is one of about 200 in the continental United States that has scheduled airline service but no tower to direct traffic. There are about 110 such airports in Alaska. Most have only a single strip of concrete; Quincy has two places where runways intersect.

Wald, M. L. (1998). Training Ordered for Controllers at U.s. Airports. ***New York Times,*** **(0362-4331).**

Abstract: A near-collision by two big passenger jets at La Guardia Airport in April has prompted the Federal Aviation Administration to order retraining for the 10,000 air traffic controllers working in airport towers nationwide. A US Airways DC-9 arriving at La Guardia on April 3 flew under a departing Air Canada A-320, the two planes missing each other by as little as 20 feet, according to the F.A.A. The near collision had not been previously disclosed, in part because information about it was not forwarded properly for investigation and agency officials therefore did not learn about it until several weeks later, the F.A.A. said. Agency officials said a controller at the La Guardia air traffic tower had promptly informed his supervisor, but the supervisor did not properly report it to his superiors.

Warwick, G. (1997). Beating the weather. ***Flight International, 152*****(4593), 56, 57.**

Abstract: The goals of NASA's Terminal Area Production (TAP) are to allow more operations per runway and more runways per airport in conditions of deteriorating weather. TAP has conducted the Low Visibility Landing And Surface Operations (LVLASO) program to allow full-tempo operations to continue as weather worstens. LVLASO involves rapid use of exits by aircraft upon landing, the provision of taxi guidance and traffic information in low visibility, and the accurate detemination by ATC

of approach spacing.

Washburn, G. (1991). Close Call at Midway Is Probed. *Chicago Tribune*.
Abstract: The FAA on Sep 27, 1991 was investigating a near collision between a Southwest Airlines jet and a smaller plane in an incident that raised new questions about the safety of the airspace around Midway Airport.

Wickens, C. D., Mavor, A. S., Parasuraman, R., & McGee, J. P. (1998). THE FUTURE OF AIR TRAFFIC CONTROL. HUMAN OPERATORS AND AUTOMATION. Washington DC: National Academy Press.
Abstract: This book focuses on the interaction of air traffic controllers and pilots, with a growing network of automated functions in the airspace system. The book explores ways in which technology can build on human strengths and compensate for human vulnerabilities, minimizing both mistrust of automation and complacency about its abilities. The panel presents an overview of emerging technologies and trends toward automation in the national airspace system in areas such as global positioning and other aspects of surveillance, flight information provided to pilots and controllers, collision avoidance, strategic long-term planning, and systems for training and maintenance. The book also examines how to achieve better integration of research and development, including the importance of user involvement in air traffic control, and discusses how to harmonize the wide range of functions in the national airspace system, with a detailed review of the free flight initiative.

Wiker, S. F., Kennedy, R. S., & Pepper, R. L. (1983). Development of Performance Evaluation Tests for Environmental- Research (Peter) - Navigation Plotting. *Aviation Space and Environmental Medicine, 54*(2), 144-149.

Wilhelmsen, H. (1994). Preventing runway conflicts - The role of airport surveillance, tower-cab alerts, and runway-status lights. *The Lincoln Laboratory Journal 7*(2), 149-168.
Abstract: This article describes a detailed survey of runway-conflict accidents and high-hazard incidents resulting from inappropriate entry onto or movement on an active runway. The patterns that emerge allow us to determine the role that three different safety systems can be expected to play in reducing the incidence or consequences of runway incursions and conflicts. The three systems are a surface-surveillance system, a tower-cab alerting system, and runway-status lights. Judging from the history of runway conflicts, it appears that runway-status lights, operating automatically with inputs from a surface radar, can prevent over half of these conflicts. A surface radar alone or combined with tower-cab alerts promises to be effective in preventing another one-third. The three systems in combination can offer protection in an estimated 90 percent of high-hazard conflicts.

Williams, H. P., Tham, M., & Wickens, C. D. (1993). Workload Management and Geographic Disorientation in Aviation Incidents: A Review of the ASRS Data Base. In R. S. Jensen & D. Neumeister (Eds.) *Proceedings of the Seventh International Symposium on Aviation Psychology* (pp. 960-964).
Abstract: NASA's Aviation Safety Reporting System (ASRS) incident reports are reviewed in two related areas: pilot's failures to appropriately manage tasks, and breakdowns in geographic orientation. Examination of 51 relevant reports on task management breakdowns revealed that altitude busts and inappropriate runway use were the most frequently reported consequences. Task management breakdowns appeared to

occur at all levels of expertise, and prominent causal factors were related to breakdowns in crew communications, over-involvement with the flight management system and, for small (general aviation) aircraft, preoccupation with weather. Analysis of the 83 cases of geographic disorientation suggested that these too occurred at all levels of pilot experience. With regard to causal factors, a majority was related to poor cockpit resource management, in which inattention led to a loss of geographic awareness. Other leading causes were related to poor weather and poor decision making. The potential of the ASRS database for contributing to research and design issues is addressed.

Witkin, R. (1995). Near Collision Changes Takeoff Rules. ***New York Times Current Events Edition*****.**

Abstract: A near collision between a jumbo jet and a commuter plane on a runway at Dallas-Fort Worth International Airport on Feb 27, 1995 led federal authorities on Mar 3 to issue an emergency order altering takeoff procedures from sunset to sunrise at the nation's airports. The action followed an incident in which an American Airlines MD-11 from Chicago that was landing with 60 people on board was reported to have passed less than 50 feet over a commuter plane waiting for takeoff on the same runway.

Wood, M. L. (1999). ***Operational and Spectrum Tests for ATIDS at Dallas/Fort Worth Airport*** **(Report No. PB2000-100513/XAB. ATC-272). Lexington: Massachusetts Inst. of Tech.**

Abstract: To help attain the goal of seamless surveillance and identification of aircraft on the airport surface, the Runway Reduction Program (RIRP) has been developing the Airport Target Identification System (ATIDS). ATIDS is a prototype multilateration and Automatic Dependent Surveillance-Broadcast (ADS-B) system which functions with all types of Air Traffic Control Beacon System (ATCRBS) transponders; e.g. new Mode S transponders carried by all TCAS-equipped aircraft and older Mode A/C transponders. ATIDS uses the pseudo random squitters of Mode S transponders to obtain position and identification information. The RIRP team, which includes the FAA Volpe National Transportation Systems Center, Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL) and Trios Associates, Inc., has conducted interference tests at Dallas/Fort Worth Airport (DFW) to quantify the impact that ATIDS would have on that high-use environment. The tests included environmental 1030/1090 MHz measurements, ATCRBS false target investigations, and Mode S reinterrogation tests. This document reports the results of these tests.

Young, S. D., Wills, R. W., & Smith, R. M. (1996). ***Pilot Evaluations of Runway Status Light System*** **(Report No. N19970001468. NAS 1.15:4727; L-17496; NASA-TM-4727). Hampton, VA: National Aeronautics and Space Administration.**

Abstract: This study focuses on use of the Transport Systems Research Vehicle (TSRV) Simulator at the Langley Research Center to obtain pilot opinion and input on the Federal Aviation Administration's Runway Status Light System (RWSL) prior to installation in an operational airport environment. The RWSL has been designed to reduce the likelihood of runway incursions by visually alerting pilots when a runway is occupied. Demonstrations of the RWSL in the TSRV Simulator allowed pilots to evaluate the system in a realistic cockpit environment.

Zelenka, R., & Almsted, L. (1996). Flight test of 35GHz MMW radar forward sensor for collision avoidance. ***SAE and AIAA, World Aviation Congress, 1st, Los Angeles, CA, Oct. 21-24, 1996,*** **(p. 6).**

Abstract: Collision avoidance is of concern to all aircraft, requiring the detection and

identification of hazardous terrain or obstacles in sufficient time for clearance maneuvers. The collision avoidance requirement is even more demanding for helicopters, as their unique capabilities result in extensive operations at low altitude, near to terrain and hazardous obstacles. To augment the pilot's visual collision avoidance abilities, some aircraft are equipped with 'enhanced-vision' systems or terrain collision warning systems. Enhanced-vision systems typically project raw images from infrared or radar sensors, and can require a high degree of pilot interpretation and attention, as the sensor returns may be sparse and are devoid of memory from previous sensor returns. Terrain collision warning systems rely on stored terrain maps that are of low resolution and accuracy which do not represent hazards to the aircraft placed after map sampling. Such hazards could include aircraft parked on a runway and man-made towers or buildings. In the present study, a scanning pencil-beam millimeter-wave (MMW) radar forward sensor is used to determine whether an aircraft's flight path is clear of obstructions. The three-dimensional radar's returns are used to construct a terrain and obstruction database surrounding an aircraft, which is presented to the pilot as a synthetic perspective display. The radar and associated display, evaluated in flight tests on a NASA/Army test helicopter, demonstrated its potential usefulness for collision avoidance.

Dissertation Abstracts Online:

ORDER NO: AAD99-24669
TITLE: CONFLICT RESOLUTION AND ALERT ZONE ESTIMATION IN AIR TRAFFIC MANAGEMENT (NONLINEAR OPTIMAL CONTROL, AIRCRAFT)

ABSTRACT: The current air traffic control (ATC) system provides separations among all aircraft through pre-defined routes and flight procedures, and active controller participation. In particular, en route separations are achieved by choices of different flight routes, different flight levels, and speed control. During the final descent approach over an extended terminal area, aircraft separations are achieved by speed changes, altitude changes, and path stretching. Recently, a concept of free flight has been proposed for future air traffic management. In the proposed free flight environment, aircraft operators can change flight paths in real time, in order to achieve the best efficiency for the aircraft. Air traffic controllers are only supposed to intervene when situation warrants, to resolve potential conflicts among aircraft. In both cases, there is a region around each aircraft called alert zone. As soon as another aircraft touches the alert zone of own aircraft, either the own aircraft or both aircraft must initiate avoidance maneuvers to resolve a potential conflict. This thesis develops a systematic approach based on nonlinear optimal control theories to estimate alert zones in two aircraft conflict scenarios. Specifically, point-mass aircraft models are used to describe aircraft motions. Separate uses of heading, speed, and altitude control are first examined, and then the synergetic use of two control authorities are studied. Both cooperative maneuvers (in which both aircraft act) and non-cooperative maneuvers (in which the own aircraft acts alone) are considered. Optimal control problems are formulated to minimize the initial relative separation between the two aircraft for all possible initial conditions, subject to the requirement that inter-aircraft separation at any time satisfies the separation requirement. These nonlinear optimal control problems are solved numerically using a collation approach and the NPSOL software line for nonlinear programming. In addition to produce alert zones in various scenarios, solutions to these problems also suggest the desirable maneuvers to resolve potential conflicts between two aircraft.

ORDER NO: AAD99-23073
TITLE: HYBRID CONTROL OF AIR TRAFFIC MANAGEMENT SYSTEMS (EVENT DYNAMICS)

ABSTRACT: Today's crowded skies and ever-increasing demand for air travel, coupled with new technologies for navigation and surveillance, are fueling a change in the way that the Federal Aviation Administration manages air traffic. Current Air Traffic Control (ATC) practice manually routes
aircraft along predefined paths between “fixes”, using radar track and flight information from plan view displays and voice communication over radio channels. The use of Global Positioning Systems and datalink communication will enable automation of some ATC functionality, such as the prediction and resolution of trajectory conflicts between aircraft. For such a safety critical system, the integrity and acceptance of new automated control functionality depends on a *provably-safe* design, which requires accurate system models, and procedures for verifying and synthesizing safe control actions.

We present a model and controller synthesis scheme for a *nonlinear hybrid automaton*, a system that combines discrete event dynamics with nonlinear continuous dynamics. The discrete event dynamics model linguistic and qualitative information, such as the flight mode of an aircraft or the interaction between several aircraft. Discrete event models also naturally accommodate mode switching logic, which is triggered by events internal or external to the system. The continuous dynamics model the physical processes themselves, such as the

continuous response of an aircraft to the forces of aileron and throttle. Our model includes input variables to model both continuous and discrete control and disturbance parameters.

We translate safety specifications into restrictions on the system's reachable sets of states. Then, using analysis based on two-person zero-sum game theory for automata and continuous dynamical systems, we derive Hamilton-Jacobi equations whose solutions describe the boundaries of reachable sets. These equations are the heart of our general controller synthesis technique for hybrid systems, in which we calculate feedback control laws for the continuous and discrete variables which guarantee that
the hybrid system remains in the “safe subset” of the reachable set. We present the extension of a level set method to compute numerical solutions of the Hamilton-Jacobi equations. Throughout, we demonstrate our techniques on examples of interesting nonlinear hybrid automata modeling aircraft conflict resolution and autopilot flight mode switching.

ORDER NO: NOT AVAILABLE FROM UNIVERSITY MICROFILMS INT'L.
TITLE: PILOT NON-CONFORMANCE TO ALERTING SYSTEM COMMANDS DURING CLOSELY SPACED PARALLEL APPROACHES (SAFETY)
ABSTRACT: Cockpit alerting systems monitor potentially hazardous situations, both inside and outside the aircraft. When a hazard is projected to occur, the alerting system displays alerts and/or command decisions to the pilot. However, pilots have been observed to not conform to alerting system
commands by delaying their response or by not following the automatic commands exactly. This non-conformance to the automatic alerting system can reduce its benefit. Therefore, a need exists to understand the causes and effects of pilot non-conformance in order to develop automatic alerting systems whose commands the pilots are more likely to follow.

These considerations were examined through flight simulator evaluations of the collision avoidance task during closely spaced parallel approaches. This task provided a useful case-study because the effects of non-conformance can be significant, given the time-critical nature of the task. A preliminary evaluation of alerting systems identified non-conformance in over 40% of the cases and a corresponding drop in collision avoidance performance. A follow-on experiment found subjects' alerting and maneuver selection criteria were consistent with different strategies than those used by automatic systems, indicating the pilot may potentially disagree with the alerting system if the pilot attempts to verify automatic alerts and commanded avoidance maneuvers. A final experiment found supporting automatic alerts with the explicit display of its underlying criteria resulted in more consistent subject reactions.

In light of these experimental results, a general discussion of pilot non-conformance is provided. Contributing factors in pilot non-conformance include a lack of confidence in the automatic system and mismatches between the alerting system's commands and the pilots' own decisions based on the information available to them. The effects of non-conformance on system performance are discussed. Possible methods of reconciling mismatches are given, and design considerations for alerting systems which alleviate the problem of non-conformance are provided. (Copies available exclusively from MIT Libraries, Rm. 14-0551, Cambridge, MA 02139-4307. Ph. 617-253-5668; Fax 617-253-1690.)

ORDER NO: AAD91-37442
TITLE: EFFECTS OF AUTOMATION ON DECISION-MAKING PERFORMANCE
ABSTRACT: Increasing automation changes allocation of functions between humans and machines. The present study investigated three modes of automation in a simulated air traffic control system for two types of operation (normal and abnormal) and two workload conditions (heavy and very heavy). Ten subjects were assigned randomly to each of the three modes of

automation. The subjects' task was to make a series of decisions when there were aircraft in conflict with each other in the air traffic configuration.

Results indicated that for mean reaction time and percent correct responses, mode of automation by type of operation interactions were significant. The mode of automation by workload condition interaction for percent correct responses was also significant. The findings demonstrated that the subjects most effective decision-making performance was in the medium level of automation for both types of operation and both workload conditions.